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Typical Dance Injuries

and

Prevention of Them

Diploma Thesis

2012

Prague

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Abstract

Objectives

Identifying the most common dance injuries of lower extremity of classically trained dancers and looking at the different possibilities of prevention. Focus is on gaining a holistic view on dancer's health; how these injuries develop in dancers specifically and different approaches of prevention, all with an understanding of the dance-specificities; including dance technique, training regimes and dancer's mentality. With this I hope to gain knowledge to be able to work in this field in the future. My questions for investigation are;

1. What are the most frequent injuries of lower extremity in dancers?
2. What are the main reasons for these injuries to occur?
3. Are the injuries in any way connected to each other?
4. What are the different possibilities for active prevention of them?

Methods

This is a literary review with the use of books and articles in the field of Dance Medicine and Sports Medicine. Articles used are gained through PubMed, Medline and Cochrane libraries, or in the "*Journal of Dance Medicine & Science*" through my membership with the "*International Association of Dance Medicine & Science*". Articles and books are found within the period of October 2010 till March 2012.

Findings

Overuse injuries with mild to moderate severity is most common. Functional disability is often high compared to injury severity. Foot and ankle injury is the most common injury location, with ankle sprains as most common specific injury/diagnosis. Due to difficulties with injury reporting epidemiological studies are found to be hard to interpret, mostly due to dancers underreporting. Technical errors are the most common cause of injury, especially use of turn-out and associated compensations for forcing ones turn-out. Almost all injuries can be linked together through technical errors and their compensations. Prevention is found to be most effective through holistic approaches, ideally involving screening, education, technical correction, improving strength and flexibility and correcting postural faults.

Conclusion

Injury development is often complex including several factors; hence the prevention must be equally complex addressing the same factors. The research field of dance medicine is quite young and unexplored and to be able to conclude properly more research must be done, and more norms and standards for investigations must be developed.

Key Words:

Dance injury, dance medicine, lower extremity injury, preventing dance injury, dancer's health.

Abstrakt

Název: Typická zranění tanečníků a jejich prevence

Cíle

Identifikace nejčastějších zranění dolních končetin při tanci u běžně trénovaných tanečníků a náhled na různé možnosti prevence. Ústředním bodem je získání holistického pohledu na zdraví tanečníka, jak se tyto úrazy objevují u určitých tanečníků a různé přístupy k prevenci, to vše s přihlédnutím k tanečním zvláštnostem, včetně tanečních technik, tréninkových režimů a taneční mentality. Na základě výše zmíněného doufám v získání znalostí, jež mi pomohou v budoucí práci v této oblasti. Mé otázky pro výzkum jsou:

1. Jaké jsou nejčastější úrazy dolních končetin tanečníků?
2. Jaké jsou hlavní důvody výskytu těchto zranění?
3. Jsou tato zranění nějakým způsobem propojena?
4. Jaké jsou různé možnosti jejich aktivní prevence?

Metody

Toto je formální recenze s použitím knih a článků z oblasti taneční a sportovní medicíny. Použité články byly získány prostřednictvím PubMed, Medline a databáze Cochrane, nebo v „*Journal of Dance Medicine & Science*" díky mému členství v „*International Association of Dance Medicine & Science*". Použité články a knihy jsou z období říjen 2010 až březen 2012.

Zjištění

Nejběžnější je nadměrný výskyt lehčích až mírných zranění. Funkční neschopnost je často srovnávána s vážností zranění. Zranění chodidla a kotníku jsou místa nejčastějšího výskytu zranění, vyvrtnutí kotníku je považováno za nejpříznačnější zranění/diagnózu. S ohledem na potíže s ohlašováním zranění je složité interpretovat epidemiologické studie, hlavně kvůli nízké míře ohlašování tanečních úrazů. Technické chyby jsou nejčastější příčinou úrazů, hlavně při otočkách, s čímž jsou spojené i opravné a vynucené otočky. Téměř všechna zranění mohou být propojena díky technických chybám a jejich opravám. Nejúčinnější prevence je shledávána v holistickém přístupu, ideálně zahrnující prohlídky, výuku, technickou opravu, zdokonalení síly a flexibility a napravení chyb držení těla.

Závěry

Výskyt úrazu často zahrnuje několik faktorů, tudíž je nutné, aby prevence byla adekvátní k týmž faktorům. Oblast výzkumu taneční medicíny je zcela neprozkoumána, a aby bylo možné vyvodit přesné závěry, je nutné provést více výzkumů a vytvořit více norem a standardů.

Klíčová slova:

Taneční úraz, taneční medicína, zranění dolních končetin, prevence tanečních úrazů, zdraví tanečníka.

Declaration

I declare that this thesis is based entirely on my own work, with knowledge gained through books, journals and articles. I have in addition been able to use some of my own personal experience from dance, and knowledge achieved through my education at Charles University, Faculty of Physical Education and Sports, Department of Physiotherapy.

This thesis was written in the period from October 2010 till March 2012.

The list of literature I have used to compose my work is found at the end of the thesis in the Bibliography.

Prague 2011

Acknowledgements

I would like to thank my professors at FTVS for their guidance during the writing of this thesis, and especially my supervisor Ass. Prof. Dr. Dagmar Pavlů, CSc. for all her recommendations and help in the entire process.

Thank you to my colleague Christer for keeping me company at the library, and all the longer coffee breaks we have had with discussions around our topics.

I would also like to thank Nina for all the conversations on dance technique and prevention; without you this thesis would not have been possible. Dance teachers at Langhaugen also deserve a thank you for letting me lecture and observe their students during my time in Norway.

Last but not least I would like to thank Simen for his patience with me and all his moral support, and my family and friends for showing such great interest in my thesis.

Iselin Guldbrandsoy

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Introduction

For large parts of my life dance has been my big passion.

I have experienced myself, and through my colleagues and friends, many of the different injuries that typically occur when training the classical styles of dance; as classical ballet, jazz and contemporary. Through my physiotherapy studies I have begun to see how most of these typical injuries might be prevented through specific changes of frequent technical mistakes, specific exercises and education of dance teachers and students.

In this thesis I have looked at the typical dance injuries of the lower extremity, why and how they occur, briefly how to treat them, and also more importantly how to prevent them. My goal when writing this thesis is to get a complete and holistic view on the injuries of lower extremity of a dancer, especially the injury development and the possible approaches for prevention; hopefully providing me with a wide base of knowledge I can practically use in my work in this field in the future.

During the writing of this thesis I have been so lucky to visit Langhaugen High School and their Department of Dance (dance conservatory) at two occasions. I myself attended Langhaugen before starting my physiotherapy education and have through my summer practice, and my job at Step In Dance Studio, been invited there to observe classes and also have lectures for the students.

I have observed mainly ballet classes and have through this gained a lot of practical training and experience in analyzing the dancers while they work, finding their weaknesses and technical mistakes. I have also had an excellent opportunity to see how the teacher's comments influence the dancers, and how they work with technical correction. I found this very useful during my writing as this gave me some practical experience accompanying my theoretical study.

When teaching the students myself I had three lectures with them, mainly concerning basic skills in anatomy and kinesiology with direct links to dance and with focus on prevention of injury. I learned a lot from this, and it also gave me an opportunity to see how I might work in the future.

Objectives

Through the writing of this thesis I hope to gain a holistic insight into dance medicine that I can practically use in my later work with dancers, dance teachers and dance students.
I have chosen a quite wide topic for investigation and feel that this will to a larger extent, compared to a smaller research based topic, give me a total insight into the dance-specific details of injuries, the dancers coping and handling of them, how the injuries can be prevented and how I can approach working within this field. I will focus my work on finding which injuries often occur, how they are developed and how they can be prevented.

I have chosen to focus on the lower extremity due to statements found in literature during my preparative work concluding that there is a higher prevalence of injury in the lower extremity compared to upper extremity and trunk. I have also chosen for this reason to include some basics of dance technique and terminology, and some specific characteristics of dancer's mentality and general health issues. By doing this I feel that my work will be more useable for me in the future and that the total picture will be more clear.

Methods

This thesis will be a literature review of the current literature regarding dance injuries of the lower extremity and prevention of them.

Questions for Investigation:

1. What are the most frequent injuries of lower extremity in dancers?
2. What are the main reasons for these injuries to occur?
3. Are the injuries in any way connected to each other?
4. What are the different possibilities for active prevention of them?

I will try to answers these questions using articles and books in the field of Dance Medicine and Sports Medicine. Articles are found in the period from October 2010 till March 2012 using Pubmed, Medline and Cochrane libraries. A large extent of the articles used are from the "*Journal of Dance Medicine & Science*" and gained through my membership with the "*International Association of Dance Medicine & Science*" ;being the leading association in the field of dance medicine. I have full access to all articles in this journal published from 1997-2011, volume 1-15.

Work Structure:

Chapter 1 deals with the special aspects of dance, including a review of dance technique, terminology and special considerations as nutrition, equipment and mentality. The purpose of this is to get a slight introduction to the field of dance and dance medicine, so to have a more holistic view of the later chapters. *Chapter 2* is an introduction to injuries in dancers; dealing with epidemiology of injuries and general causes for injuries. *Chapter 3* describes the most frequent injuries of the lower extremity, divided according joints. I will shortly review epidemiology, etiology, clinical picture and treatments of these injuries. *Chapter 4* deals with prevention of injuries and different techniques often used for this purpose. *Chapter 5* will summarize my findings and give answers to the investigative questions stated in the text above. *Chapter 6* is a discussion around the findings with my thoughts and opinions of the findings, and *Chapter 7* a conclusion to my work with this topic, and my own thoughts upon finishing this work. *Bibliography* is found in its own chapter and all sources are listed using iso 690 numerical format automatically done in Microsoft Office Word. *Tables and Appendixes* are found on the last pages.

Inclusion Criteria:

- Lower extremity injury
- Classically trained dancers; classical ballet, jazz, contemporary/modern
- Professionally trained dancers; including dance students at conservatories and professional dancers of companies and/or freelance.
- Both genders
- Dancers with 15-30 years of age
- Dancers and research from Europe and USA
- Articles, journals and books written from year 1990 till 2011 in field of Dance Medicine, Sports Medicine and Physiotherapy.
- Preventive means of active character

Exclusion Criteria:

- Injury to spine, trunk and upper extremity
- Aerobic dance, break dance, hip hop, standard and latin dance.
- Leisure time dancers
- Retired dancers
- Articles and books written before the year 1990
- Passive means of prevention
- Dancers and research outside Europe or USA

Key Words: dance injury, dance medicine, lower extremity injury, preventing dance injury, dancer's health.

1. Introduction to Dance

There exists an incredible amount of different styles of dance, and also thereby a large amount of different dancers, dance schools and training techniques. Most of the styles frequently seen today all base their techniques, and have an origin in, the "old" classical ballet. I will focus my work on these classically trained dancers, meaning dancers trained in ballet, or styles originating from ballet, as jazz and contemporary/modern.

In literature dance is usually classified into four basic disciplines; ballet, jazz, modern and folk. Sometimes a fifth category is mentioned, theatrical or Broadway dance, but this is usually a combination of ballet, jazz and modern in a show or performance (1).

There is one thing common in all dancers; their job is to create "*effortless movements at the extremes of motion*." (2) Dance is an art form where the body motion is used to express and communicate. Even though it through performance looks easy, the dancer usually spends most of his or her life training and perfecting their technique and aesthetics.

But dance is not only a performing art (3) (4) (5).Classical ballet differs from other pure artistic fields in the presence of high athletic performance. Vice versa it differs from other sports in being as artistic as it is (6). Breder et.al (5) tries to define what dance is and says; "*First when a movement goes from being just a performance of a skill to an esthetical act, you are talking about dance*". They state that the physical and athletic demands to a large extent are formed by the esthetic norms in dance. Delmas J. Bolin (7) states that in the world of organized sport ballet is unique, as participants often start training at 6 years old or even younger. In addition it places these young athletes under enormous physical and psychological pressures due to the high emphasis on form, both in movement and body habitus, and high requirements on technique from early childhood. With all the unique requirements of ballet it is logical that treatment of dancers and their injuries also needs to be unique (8).

In a study comparing different sports, including football, rugby, boxing and hockey, they concluded that classical ballet is one of the most demanding (3). Several studies have concluded that ballet dancers are under large amount of stress, and this mostly due to factors as; high artistic excellence, keeping an unrealistic body weight, exhausting training regimes, fierce competition and lack of job security (6). Samuell Bennet of the Chicago Ballet has been cited in saying he believes "*that many dance injuries are the result of attempting to achieve a physical ideal that probably doesn't exists"* (9).

The injuries that occur in the dancer's life have often been found challenging to treat for many different reasons. Amongst other issues it is said that many physiotherapists do not understand the physical demands and loads that are put on the dancer in their work and training, nor have an understanding for the terminology and practical technique (10), all being important to properly treat a dancer or develop preventive means (8) (11). I will later in this thesis try to gather all the special considerations needed to care for the dancer.

As dancers are primarily affected by overuse injuries the understanding of the technical errors that has often been noted to cause them are an important factor in the rehabilitation. For this reason a multidisciplinary approach to the injuries of the dancers are important (7) (12) .

Dance medicine is a relatively new discipline (4) (13) (14) but has the recent years expanded greatly; and is starting to form its own subspecialty in the field of medicine and rehabilitation. Dance injuries has been referred to as the "orphan child" of the sports medicine family (1). A dancer's technique, environment and mentality are "*unique among athletes"* (3) (8), and in my opinion deserve this newly started branch of research and medicine.

One of the main reasons for me to be largely interested in this topic is the fact that I know so many in the dance community that will not seek physiotherapy or doctor help when injured due to their previous experience that the knowledge on their work an terminology is lacking, and that the only response they are given is to "stop dancing". During my review of the literature this is also supported by several authors. Krasnow et.al (15) is especially sited when this topic is discussed and her opinion is also that medical personnel lack experience and knowledge on dance, distancing themselves from the dancers. Many dancers feel that the doctors do not understand their work, and situation, thereby being quick in their instructions to stop dancing, again telling them to end their career (3) (15)

Research shows that dancers have a tendency to seek help from non-physician health-care providers (4), with less than 50% seeking care from physician (3). This has been said to be alarming when you consider the amount of injuries reported in the dance world (15). Several authors state how not only dancers have a tendency to not seek medical help when injured, but often look upon injury as an essential part of their vocation, making pain and injury a natural part of their life, and putting themselves at risk for chronic injury (15) (16). Krasnow et al (15) state the following to be reasons for dancers to avoid medical care; financial considerations, accessibility to appropriate medical professionals, time, dancer's perception of

the medical field, social culture of the dance world, fear of loss of employment and perceived personal changes.

Dancers also tend to be very impatient and eager to return to their work and therefore it may be very important for a physician to explain properly the reasons for treatment and restitution (9). Due to dancer's constant motivation to return to dance, rehabilitation may be inadequate and a premature return may contribute to both chronic and traumatic injuries (8).
Dancers that do visit physicians often get the reputation of being "*difficult patients*" (3), due to their mistrust of the system. It is therefore very important to try to *"speak their language"*, and have an insight to their lifestyle and work (15). Technical correction is often necessary in rehabilitation and treatment of dance injuries, and it has been stated that due to fear of peer disapproval young dancers often avoid changing their faulty technique (16).

In research on communication between dancers and medical personnel Lai, Krasnow et al (16) found that both dancers and medical practitioners agreed that communication on a broader range, including dance teachers and choreographers, was necessary to fully rehabilitate a dancer. Practically, however, this was not the case to be found. The research also found how both medical practitioners and dancers agreed that anatomical knowledge would help dancers in their career. The authors state how incorporation of dance science to dance training may be beneficial.

In the previous years the focus on "the healthy dancers" has improved some of above discussed issues. Thomas and Tarr (17) states that in a survey done in 2002 in UK, 60% of the dancers seek professional help when injured, compared to the same study done in 1993. It should be noted however that the later study included high percentage of students.

1.1 Dance Technique and Terminology

For providing the best treatment and diagnostics of dancers it is absolutely necessary to have a basic understanding of the basic positions and common movements that the dancers provide on a daily basis (1) (8) (12) (15). For a physiotherapist to have a complete understanding of the physical load on the dancer's body it is necessary to understand both the dancers' language and exercise regime, and also the styles of dance and its characteristics should be assessed (12). The following descriptions of positions and technique are based on my own experience and education in dance, and also through Breder et.al`s (5) book on dance theory.

There are five basic positions of the lower extremity, and all movements are done in the turn-out position, an external rotation of the whole lower extremity. Following is an introduction to the classical positions and the basic terminology, that I consider a minimum needed to treat the dancers and also to follow this text further.

Turn-out:

This position is the primary position of the legs in ballet. The whole lower extremity is externally rotated, optimally from the hip, and kept in this position throughout the choreography or exercise. The "*perfect turn out*" position is 90 degrees external rotation of both legs, a total turn-out of 180 degrees. Done correctly the rotation is occurring in the hip joint, without compensatory rotation in knees and ankles. According Shah (3) sixty percent of the perfect turn-out is achieved from the hips by retroversion of femur, and 40 percent is from knees and feet. She also states that elite dancers are ideally able to perform the turn-out without causing excess valgus knee stress, excess tibial torsion, pronation of the feet or lumbar lordosis. Other researchers agree and the common statement in literature is that approximately 60% of the turnout is from the hip (18) (19) (20).

Grossman (18) states that the total amount of turn out cannot be measured solely by hip external rotation. She states that knees, tibia and ankle are naturally contributing to the turn out, and for a complete evaluation in dancers all these joints must be included. In the knee one usually finds 10 degrees of rotation as the knee locks on the tibia, this occurring naturally and without causing damage. Likewise tibial torsion occurs and contributes to the total turn-out, usually with 10-18 degrees, and talocrural out-toeing may contribute up to 6 degrees.

The turn-out position, being looked at as one of the most important qualities in ballet (18) (19) (20) (21), has a tendency to be done with errors. As most dancers have problems obtaining the perfect turn-out, the frequent mistake is to add rotation in knee joints, or ankle, to obtain the

"perfect position" with 180 degrees. A frequent observation is that the dancers, when standing at their maximum turn out, bend their knees slightly, push the toes further outward, and then extend the knees again, now with a "false" improvement of the turn-out. This is resulting in tremendous rotational stress on the knee, especially the medial collateral ligament and medial menisci (9) (18) (22). A correct turn-out is essential for both skill development and injury prevention (20).

Dance teachers are usually strict in instructing their students to turn from the hip, and always to have "knees over toes", but from my own experience you also find teachers who facilitate the "false turn-out" and are more interested in the esthetics then the correct technique.

A study done on the external rotation in dancers show that greater external rotation range of motion is not a sole prerequisite for dancers, but more the ability to produce greater force in the higher degrees of external rotation. The same study also concluded that the larger range of external rotation in dancers are on the expense of the internal rotation, where all subjects tested showed less internal rotation then the test group of non dancers. (2)

The perfect and total turn-out involves femoral neck anteversion, femoral torsion, knee alignment, tibial torsion and foot alignment. (22)
For more on turn-out see chapter 5; causes of Injuries.

<u>The five basic positions of feet:</u>
1st position; the heels are touching each other and toes are turned outward from the body. In a perfect turn out the two feet will form one straight line.
2nd position; between each heel there is a distance of approximately one foot, and the whole leg is turned out. If there is a perfect turn out the two feet will form one line, but with distance between them.
3rd position; one foot is in front of the other, with the heels touching the middle medial side of the other foot.
4th position; the same as third position but with approximately half a foots distance between the feet.
5th position; There are two different variations on the fifth position depending on the style you are trained in (21). In the Cecchetti method the heel of the front foot is directly in line and contact of the big toe of the back foot. In the Russian method the feet are crossed even more,

and the front foots heel is at the tip of the big toe of the back foot. In both styles the feet should optimally be in contact at all points, and both knees fully extended.

Point:

When a dancer is saying "I have pain when I am pointing" they are referring to the position of maximal plantar flexion in the ankle. This position is used always when lifting the foot from the floor, unless something else is specified.

Dancing "on point" is referring to the use special shoes and dancing on tip toes; meaning carrying the whole bodyweight on the toes, especially the great toe. This requires the dancers to have minimum 90 degrees plantarflexion, which is stated being 123% above average (3).

Dancing on demì-point is referring to a situation where the dancer is not dancing on tip toes, but dancing with maximal lifting of heels from the floor with the weight carried on metatarsal heads.

Pliè:

This means bending the knees. A pliè can be done in all the basic five feet positions and is used to prepare joints for movement, protect joint from the impact of a jumps etc, and it is said to be the "*key to elevation"* (21). During the pliè some of the main struggles are to keep the neutral spinal position, accompanied with a sensation of stretch upward of the body, and keeping the turn-out of legs.

There are two types of pliè; *demì* and *grand*. *Demì-pliè* is half-bending of the knees, and the heels should not be lifted from the ground. *Grand -pliè* is a full bend of the knees, usually till the thighs are in a horizontal line. In second position grand pliè the heels are not lifted from the floor.

The pliè should be gradual and fluent, and at the same tempo in descending and ascending. When ascending you push the heel to the floor as soon as possible. The pliè is used in the barrè exercises for warming up, but also when landing from jumps or as a part of another step in choreography.

Relevè:

Relevè is rising of the whole body, either to demi-point position or point position. Relevè can be used by itself during warming up, or it can be used to complicate other positions, for example a relevè during arabesquè.

Arabesque:

This is one of the "typical" poses in ballet. There are several variations in the different systems of ballet, but the main principle is lifting of a straight leg to the back with trunk kept upward and combined with different arm positions. The leg is in turn-out.

Attitude:

This is also one of the "typical" poses in ballet, and looks similar to the arabesque. The main principle is lifting of one leg, either to the front or back, with semi flexion of knee. The trunk is held up, and it is combined with positioning of the arms. The leg is in turn-out position.

In dance there are thousands of terms and special words describing technique and positions, and thereby the surprisingly large amount of "dance dictionaries" in both book form and online. I will only describe these few terms, as they are the main basics, and will be included in large parts of the rest of my work.

When it comes to the different styles of dance and respecting the differences between them a good example of this importance can be made through research done my Solomon et.al , reviewed by Jenkinson and Bolin (1) in 2001. They found a clear correlation of styles of modern dance to incidence of knee injury. In their analysis they found a difference between styles that compress and hyperextend the knees (Graham Style: 25% knee injury) and styles that flex and strengthen the quadriceps (Horton Style: 10.8% knee injury). This shows how the style of dance, and the way the dancer trains, will affect the injury and also how they can handle them. Examination, diagnostics and treatment thereby needs to be custom made to fit the style of dance, not only generally "dance". In the same manner gender can play a role, and it has been seen that males have higher rates of "Jumper`s knee" of patellar tendinitis, as they tend to jump more than females (1). Males also never reach full en pointè position, and tend to do more lifting.

1.2 Special Considerations When Dealing With the Dancer

In addition to the special terms, positions and technical aspects of dance there are also some other special things to take to consideration when treating dancers. These include nutrition, psychology and equipment, and in this chapter I will discuss shortly also these aspects.

1.2.1 Nutrition and Female Athlete Triad

Almost all my references agree that one of the factors involved in injury development in dancers is their nutrition, weight and/or views of those. Bolin (7) states in his review article on stress fractures in dancers that several of his revised studies show that inadequate nutrition and disordered eating is highly linked to injury.

Ballet requires a very specific body type to reach the highest levels (23), and also requires adequate food and energy supply appropriate to the high energy loss in the constant training. These two contrasting needs tend to give the dancers different problems as tiredness and exhaustion, and also contributing to other injuries as acute stress fractures. To achieve the long and lean figure ballet dancer often restrict their dietary intake or engage in abnormal eating behaviors (24). In the longer run the result may be as serious as female athlete triad.

A ballet dancer with ideal weight according normal medical standards might be looked at as obese by the artistic director of a ballet company (9), and many female dancers are considered underweight by the WHO criteria (3). It has been found that student and adolescent ballet dancers, especially females, consume less than 70-80% of the recommended dietary allowance, and often weigh 10-12% below ideal body weight (24) (25).
The consideration of these aspects is very important in the diagnosis and rehabilitation of the dancer as many studies have shown that the very thin dancers often have a protein and carbohydrate deficiency which makes it difficult for the body to build, maintain and repair any damage, and thus preventing proper and normal rehabilitation. (9)

Several studies show that dancers, and especially ballet dancers, have a higher prevalence of female athlete triad then woman in many other sports, and are obsessive about their body weight (3) (20) (23) (24) (25) (26) (27).
The triad is a complex condition comprised of three pathologies; amenorrhea, disordered eating and osteoporosis (28). The triad is especially prevalent in sports that emphasis the aesthetics and thinness of the athlete, as gymnastics, dance, figure skating, running, swimming and diving (25) (29). As a result of bad nutrition, not consuming enough energy to

meet the energy demands of the body, the hypothalamus, responsible for endocrine activity, affects the menstrual cycle and production of estrogen, this in turn affecting the bone mass giving higher risk of osteoporosis and fractures (30) (31). Doyle-Lucas et al (25) states in their research article that low energy availability appears to be the key component for the development of the other aspects of the triad.

The American Collage of Sport Medicine states that the three conditions can't be viewed or treated separately and that in the occurrence of one, suspicion of the syndrome needs to be raised (20).

1. Disordered eating:

   Most female athletes do not suffer from eating disorders per definition (28), but limit their caloric input compared to their energy output. This mostly being termed a "bad eating habit".

   The precipitation factor in the triad is an energy imbalance caused by insufficient energy intake to meet the needs of the body. The energy intake will affect all body processes, including thermoregulation, growth and reproduction (31).

   There is a wide use of terms for this part of the triad. Disordered eating, eating disorder or bad eating habits are all terms used in the literature. This being quite confusing and difficult to comprehend, many have tried specifying a special term for the female athletes. Brunet (28) states that using the term eating disorder might limit the diagnostics of the athlete triad as the specific eating disorders have strict diagnostic symptoms. Meaning many of the female athletes will not meet the criteria of for example bulimia, but they still have a problem with their nutrition, being sufficient to include suspicion of the triad in his opinion.

   Many athletes experiment with different ways to lose weight, including drugs as diuretics, laxatives and special dieting pills, but also by vomiting, not eating and excessive exercise (29). All trainers, teachers and physiotherapist should be aware of these methods to try to both prevent these drastic means, and also educate the dancers in the different side effects and dangerous consequences.

2. Amenorrhea:

   Amenorrhea is the lack of the physiological menstrual cycle and may reflect a hormonal change in the body (28).

   Previously it was believed that amenorrhea in athletes were due to excessive exercising, but it has in the recent years been shown that the underlying cause is not the amount of exercise but the inadequate food intake, again affecting estrogen levels (28) (32) (33). The change in estrogen levels is quite serious as this will affect the bone mass and may cause bone loss, thus resulting in the other part of the triad; osteoporosis. Another critical issue to take to mind regarding this is infertility.

3. Osteoporosis:

   Woman with low estrogen levels and low energy availability are at higher risk of developing osteoporosis, as the estrogen protects the bone from resorption. Poor nutrition may also result in deficiencies in calcium and vitamin D, also contribution to bone resorption (33). The osteoporosis will decrease the bone density and bone mass and frequently leads to higher risk of fractures.

The three corners, hence three different pathological states, of the triad are correlated in both physiological and psychological ways (33). There is a constant psychological stress to perform better and to have lower weight, resulting in increased training and decreased caloric intake. This, together with the physiological stress hormones of the body, will produce endocrine changes in the menstrual cycle, again resulting in amenorrhea. The amenorrhea over longer periods will affect the bone, leading to osteoporosis.

Recognizing the triad is the first step in treatment (32), and preventive means are likely to be more effective then treatment (29) (33). There are no pharmacological agents that can reverse the consequences that the female athlete triad has (25). Prevention should include education in both nutrition and basic physiology, optimally from adolescent training (25), and it would also be optimal if dancers at high levels were frequently controlled by medical personnel. But, many dance companies are non-profit organizations and have to small budgets to be able to afford frequent medical help to their dancers (3).

Doyle-Lucas et.al (24) developed, and examined the effects of, an educational intervention program for adolescent ballet dancer regarding nutrition habits and female athlete triad. The program was DVD based, and was found to successfully improve the dancer's knowledge of

nutrition, perceived severity of female athlete triad and self-efficacy for adopting healthier dietary habits. This research shows that one can change, or at least improve, today's negative development when it comes to nutrition in dancers, thorough these preventive means. However, some state that the prevention is often made extremely difficult due to the nature of the sport, as athletes are usually resisting to increase weight, decrease exercise load and take the oral contraception (33). Usually admitting to any kind of problem with health can be difficult.

1.2.2 Equipment

Like in other sports the equipment used has its part in both injury and prevention.

The footwear in dance varies to large extent dependent on the style, and as with other sports footwear has the potential to enhance or restrict movements (34). Ballet dancers start their training by using ballet slippers with soles of thin leather, similar to a sock, often called soft technical shoe (34). Later the female ballet dancers start using pointè shoes allowing them to keep body weight on their tip toes. These shoes are made of a solid toe box and are attached to the foot by ribbons of fabric around the ankle. The sole of these shoes are usually stiff, but dancers normally adjust them for a more aesthetic point, thus reducing the stability function of it.

It is commonly though that the use of pointè shoes have a very negative effect on the dancers feet and injury development. In a review article on this topic from the Journal of Dance Medicine and Science (34), they state that through literature and research it has been found that even though ill-fitted pointè shoes may cause bunions, corns, blisters, neuromas or digital abscesses, they have been found to aid stability of foot when on pointè and that they do not increase the likelihood of ankle or knee instability. However they state that the common opinion is that the footwear is inadequate and could be a risk factor in injury.

One of the big concerns of dance students, and their parents, is when the child can be put in pointè shoes. Many ballet schools have their own set of rules for when the children should start working "en pointè", but in my opinion this is a highly individual thing, as it depends on the child's strength and not on the child's age. George Balanchine, one of the most influential ballet choreographers of the 20th century has been quoted in saying that there is no reason to put a child en pointè until she is strong enough and well trained enough to actually do something once she is up there (9). Research done through questionnaires (35), on the topic of

pre-pointè evaluation of students, show that most dance schools have age as their main criteria for assessing when a child is ready to start pointè work. He authors stress the importance of also including previous injuries and technical skills, as relevè stability and pliè stability, into the evaluation. They also state that schools with healthcare providers included to the staff have more detailed evaluation of students.

When eager children are put in pointè shoes before being ready for it a common problem is "knuckling down" (9) of the toes, meaning that the toes collapse inside the shoe so that the dancer is dancing on the interphalangeal joint rather than tip toes. This problem is easily hidden inside the shoe and will cause all the body to be out of balance, prevent development of proper technique and in the long run possible cause injury.

It is also extremely important that the pointè shoes "fit like a glove", and they should not be bought to "grow into" (9), and to be the best ballerina the way to do it is not to start pointè work as soon as possible (35).

The modern dancers to a large extent dance barefoot; thus making them more dependent on the quality of the floor and their own technique to prevent injury.

Jazz dancers use many different types of shoes, depending on the dancer, teacher, type of jazz and floor. Some wear the classical jazz shoe; a thin leather shoe with a thin sole similar to the ballet shoe. Others wear the jazz sneaker which resembles a classical training shoe with a thick sole that is split in the middle to allow point. These are not that much used as many dancers complain they "lose contact with the floor" (3).

As in other sports the footwear may play an important role in the injuries, especially concerning instability of the ankle, or injuries related to landing from jumps. When looking at the different shoes worn in dance one will at once see that they almost always exhibit no stability or shock absorbing functions (26).

Floors also play an important role (26), especially as the environmental factor for dance injuries (19).For most people the floor is not considered when evaluating an injury, but dancers know how the quality of the floor can affect their health and performance (9). Most dance studios have wooden floor which are "sprung" from underneath, giving shock absorption. The lack of spring may produce injuries, especially to foot and lumbar region, but also problems during landing from jumps. Research on this topic, by Hackney et. al (36), shows that sprung, or suspended, floors have a positive effect on injury prevention as it helps

absorb some of the shock during landing from grand jetè (split leaps). As mentioned previously shock absorption of footwear in ballet is limited, and any energy absorption must then come from the floor. They believe that the prevention of injury by these floors are due to decreasing the intensity of the eccentric muscle contraction when landing.

Slipping is another important aspect of floors. Some studios have a vinyl cover to prevent slipping, and where rosin is used it is important to clean the floor regularly to prevent build up on the floor, again making the feet stick to the floor. When dancers are in performance the floor cannot be controlled, and many dancers feel that the unsecure or hard surface floors contribute to injury by being a stress factor. Often tours and performance in done on heavily racked stages, this producing a change in the dancer's weight bearing, again producing associated problems. (19)

1.2.3 Mentality of the Dancer

Almost all articles, books and journals I have read have their own paragraph concerning dancer's psychology and mentality, often classifying it is unique or special. There have been done numerous studies trying to see the reasons for the dancer's unique appraisal and coping with pain, and this aspect of dance medicine is largely studied.

Most dancers believe that dance perfection is more important than their personal health (3), and dancers have been seen to push their limits beyond what is considered normal for athletes to enhance their performance (37). This extreme motivation and strive for perfection often leads to overtraining and fatigue, and in turn injury (8). A large pressure to perform has also been seen to interfere with the management of injuries that dancers obtain, as they tend to ignore symptoms and delay medical treatment (7). Possibly the large number of dance students and low number of available jobs and places in companies leads to an increased effort in trying to push oneself beyond one`s limits (35). Dancers have a tendency to "dance their way into shape, when rehabilitation by other means would be more effective (38), and a prescribed rest or decrease of activity is often what dancers fear the most (1).

Ballet distinguishes itself from purely athletic or artistic fields in that it combined the demands of both fields (6). Due to this the dancers are exposed to enormous amounts of stress, including expectations to be highly artistic, keep low weight, continue demanding training, involvement in fierce competition and the total lack of job security. In addition to this the dancers have no "off-season" like most other sports (37), this placing them under constant load and pressure all year around. Research (11) has also found that 90% of ballet

dancers in a professional company have less than 60 minutes of rest during a working day. They state that many dancers have perceived fatigue and overworking to be a factor in their injuries, and they further conclude that once the dancer is fatigued the ability to perform correct technique is decreased. Through their research they found that knowledge on the dancer's working day may be very helpful in finding cause of injuries or prevent them, as it has been show that the typical work day often leads to fatigue.

As in the general sports culture the expression *"no pain, no gain"* (37) is also widely used in the dance world. But the famous "*the show must go on"* (37) is probably the most used "excuse" to continue with either training or performance while injured or in pain. It seems that ignoring both pain and injury for some reason is expected in the world of dance, and that harm or suffering does not triumph the need to continue with working.

Several studies conclude that there exists a near relation between stress and injuries in dance, but the direction of the relationship is not clear. Adam, Brassington, Steiner and Matheson (6) concluded, from their research in 2004, that there was a significant positive relation between absence due to injury and stress states as tension, anxiety, depression and anger. They also state that dancers with higher amounts of absence reported higher levels of these stress states, and also experienced sleep disturbances. They concluded their finding with saying that all the stress factors mentioned may predispose the dancers to become injured, but also that wear and tear of professional dance training may lead to the psychological stress, again finding it difficult to identify the direction of the relationship.

Another study was done in 2008 by Anderson and Hanrahan (37), addressing the area of how dancers handle pain. Trying to find how the dancers are reacting to pain and their way of coping with pain. They state that athletes in general experience two types of pain; performance pain and injury pain.

Performance pain is described as acute, short in duration, produced voluntarily, under control of the athlete, without feelings of fear or threat, and often perceived in a positive way giving feelings of satisfaction.
Injury pain on the other hand is usually chronic, outside the athletes control and thereby acting as a threat on their ability to perform, perceived in a very negative way. They state the importance of differentiation between these types of pain in the dancers, and how the proper differentiation can help them to prevent injuries and absence from work. In other words, respecting the pain and treating the pain in an appropriate manner.

They also found that dancers, unlike many other athletes, do not differentiate between the two types of pain. Both performance and injury pain is appraised in the same manner, and the notion of "toughing it out" is used for both types of pain, even though more appropriate for only performance pain. When pain is recognized it is usually coped with in a catastrophing manner, but considering the impact an injury has on a dancer it is in my opinion understandable. From my personal experience being injured in the dance world means you are out of work.

Anderson and Hanrahan (37) conclude that dancers should be educated in the different types of pain, and how to cope with them, for prevention of serious injuries and thereby prevent long sick leaves. If dancers are able to define when an injury has surpassed the performance pain level they could seek help or start prevention before there is progression to a more serious state.

I believe that all of these aspects should be included in our dealing with the dancer. I think it is very important to have an understanding of the pressures they are under, economical, artistic and athletic, to fully understand their injuries and how they are handling them and need to handle them. I also believe that dancers have a passion for dance, they dance because the love it and can't live without it, not because they have to. They consider it their love and lifestyle, not work. So therefore I believe dancers will seldom stop dancing when people tell them to, they will continue until not being able to dance anymore.

In addition to these special considerations it will also be important to know the differences between the styles of dance, and how they load the body in different ways. An example can be modern dance. Even though the same style, or category of dance, the different variations among modern techniques are quite large. Graham technique is a style of modern dance that requires large amount of external rotation and abduction in the hip joints. Dancers of this technique have been shown to be more prone of injuries to knee then other dancers (3). And another style of modern dance, Horton, will be more prone to low back injuries (3).

2. Introduction to Dance Injuries

2.1 Epidemiology of Dance Injuries

To start with a clear definition of dance injuries should be noted. There needs to be differentiation between" *dance related injuries*" and "*dance injuries*". A dance related injury is one that has occurred in the course of dancing, but due to an environmental factor (19).

Defining injury and gathering data is a challenge when doing studies on the topic of epidemiology in dance. Solomon et al. (20) state that in dance the rates of injury cannot be defined by the time away from class, as dancers tend to dance through injury. Garrick (39) state that dancers do not normally present with a "minor" injury to a health professional, however these minor injuries tend to lead to more severe injuries over time. In their book "*Preventing Dance Injuries*" (20) Solomon et al. have listed the typical problems occurring when dealing with studies of epidemiology of dance injuries. These include amongst others;

- *How is injury to be defined?*
- *Who is to determine whether an injury has occurred?*
- *How are injuries to be reported and classified?*

Most publications on epidemiology of dance injuries are on ballet dancers (1) (40). Although most injuries occurring are minor or overuse problems, because of the high physical demand on dancers the resulting functional disability seen is significant (40).

Dance injuries are an important cause of class suspension, withdrawal from dance, temporary unemployment, loss of salary, or end to career. Many dancers also have a tendency to continue dancing, or returning to full performance, before appropriate treatment or recovery has been finished (39) (40), often leading to chronic or traumatic injuries (8). From my own personal experience I also know that the psychological stress of being away from training is much worse for the dancer then the injury itself or the pain related to it. They will not seek help in fear of the medical personnel telling them they need to take a break from training or totally stop their work. These psychological considerations will be discussed later.

The following citation from Solomon et al. represents the average of the most frequent finds regarding injuries in dancers;

"Dance injuries most commonly occur on the lower extremities (52%), back (22%) and neck (12%). In the lower extremities, ankle and foot problems are most prevalent, followed by knee and the hip. Many of these injuries are considered preventable." (20)

Harkness Center for Dance Injuries (41) has collected epidemiological study-results in a scheme that can be found on their website (42) (Appendix 1). This scheme summarized the findings from 1984-1998 and one can see clearly from this that the lower extremity is the most common site for injury.
Below is a scheme of statements found in the literature I have assessed and the articles and books supporting them;

STATEMENTS **found in literature**	**SUPPORT** **from literature**
Lower extremity injury is most common, compared to other body parts.	(3) (4) (7) (8) (12) (20) (26) (40) (43) (44) (45) (46) (47)
Overuse injury is the most common type of injury.	(3) (4) (7) (8) (9) (12) (17) (20) (26) (40) (43) (44) (48)
Foot/ankle is the most common injury area of the lower extremity.	(3) (4) (12) (19) (26) (40) (44) (45) (47) (49)

(Table 1)

Gamboa et al. (45) concluded their study of injuries in dance students at a dance conservatory with the following: "*53% of injuries occurred in the foot/ankle, 21.6% in the hip, 16.1% in the knee, and 9.4% in the back."* They concluded that their findings were similar to other related studies.

Even though this is the reoccurring percentages for ballet dancers, some studies done specifically on modern dancers conclude that for these styles the low back injuries are the most frequent (17). In contrast to the rigid and stiff torso mostly kept in ballet the modern dancer's exhibit more free movement of the upper body, potentially creating more back injuries (4). The modern dancer performs excessive inversion and eversion movements of

feet, and the ballet dancer excessive plantar and dorsiflexion (4). Modern dancers usually suffer fewer injuries then the ballet dancer, with incidence two injuries per year opposed to three (3).

Most of the dance injuries occurring are overuse injuries (4) (7) (9) (17) (40) that develop slowly over time, due to the repetitive movements and loading in dance. Insufficient warm-up, fatigue, faulty alignment and technical errors are cited as contributing factors in dance injuries in over 50% of cases (17) (40). Delmas J. Bolin (7) states that there is no surprise in dancers having mostly overuse injuries in the lower extremity when considering the high demands of jumping and en pointè work.

There are numerous epidemiologic studies of dance injuries, with injury incidence 40-80% depending on the level of participation (23). Most studies conclude that the incident of injury is quite high, but that the severity of injury is lower than in other sports.

In 1996 there was done a survey study of Broadway dancers (50). 313 performers appearing in 23 Broadway companies were questioned. The results showed that 55% of the performers were injured, with a mean of 1.08 injuries per performer. Lower extremity injuries were again showed to be more common. 62% of these performers believed that their injuries were preventable. Another Swedish study reported that 95% of the dancers in the company had recent injuries resulting in time off work. This corresponds to similar findings in USA and UK. (6). A Norwegian study on the Norwegian National Ballet (47) showed that 31 of the 41 dancers experienced one injury or more. 16% of these resulted in time off from work, and they were classified as mild to moderate in severity.

Studies on the most common specific diagnosis are quite hard to find. A number of articles and books state that ankle strain is the most common injury occurring in dance, but further then that not much is research on this topic is accessible to me. I will therefore in the rest of my work base the specific diagnosis on the above list from Harkness and also the books by Howse (19), Solomon et al. (20) and Bracilovic (22), all important books of dance medicine.

Harkness Center for Dance Injury (51), being one of the world's most influential centers for dance medicine, has the following listed for most common injuries of the lower extremity:

Foot and Ankle	**Thigh and Knee**	**Hip**
Dancer`s Fracture	Anterior Knee Pain	Trochanteric Bursitis
Sesamoiditis	Knee Hyperextension	Snapping Hip
Hallux Valgus and Bunion	Patellar Malalignment	Iliacus Tendinitis
Hallux Rigidus	Patellar Femoral Syndrome	Piriformis Syndrome
Plantar Fasciitis	Patellar Tendonitis	Femoral stress fracture
Metatarsalgia	Plica Syndrome	Osteoarthritis
Achilles Tendinitis	Meniscus Tear	
Trigger Toe/FHL Tenosynovitis	Medial Collateral Ligament Tear	
Posterior Impingement Syndrome	Anterior Cruciate Ligament Tear	
Anterior Impingement Syndrome	Osteoarthritis	
Lateral Ankle Sprain		

(Table 2)

Regarding timing and occurrence of injury; a study done in 2011 by the British Journal of Sports Medicine (52) on dance students concluded that there seemed to be a higher injury occurrence during periods of performance than during period of class training. A similar study done in Germany on dance theater's (53) showed that 44.6 % of accidents leading to injury happen during rehearsals, 42.4 % during performances, 76.7 % on stage and adjoining areas and 10.7 % in the ballet studio.

Other special epidemiology aspects to consider are the age, and sex of the dancers. Female ballerinas have an average age range from 26-27, and modern dancers average of 30 years. Usually males have to endure more performances then females, probably because there are fewer men in the business (3). Dance is overall an activity with largely female participation, and due to gender differences females also have been found to have more injuries. These gender differences include; higher ligamental laxities, lower muscular development, lower proprioception, wider pelvis, genu valgum and external tibial torsion (8).

2.2 General Causes of Dance Injuries

"*All dance injuries are caused by faulty technique*". (19)

This is the way Justin Howse decided to start his chapter on causes of dance injuries. Even though there are some injuries (more correctly termed dance-related injuries) caused by other factors, most of the true dance injuries are due to errors in the dancer's technique (1) (12) (19).

When reviewing literature on the subject of *causes of injuries* most of the literature available in both medical libraries and throughout the International Association of Dance Medicine & Science refer to Howse when dealing with this subject. To me it seems he is the first, and maybe only, to have collected these causes in an organized matter (19). Even though he is the only one presenting lists on these subject, other authors seem to agree as they refer to him when dealing with causes of injuries.

All specific causes of specific injuries will be mentioned in the later chapters concerning diagnosis, but I would like to list some of the frequent and reoccurring general causes.

2.2.1 General causes of Injury

Anatomical causes: referring to restrictions given by anatomy of the individual dancer. The most typical being anatomical limitations into turn-out. It is important to respect these limitations and learn to work within them. (19)

Knowledge: referring to dancers not being fully educated in the techniques and how to properly use them, or in the prevention of the injuries. This point being especially regarding young dance students. (19)

Bad teaching: neglecting to appreciate the students anatomical limitations, weaknesses or technical faults may contribute to the development of injuries. Also directly teaching faulty technique, typically encouraging over turning in the hips, will lead to complications for the student. Placing students to early in pointè shoes is also the teachers responsibility, and thereby apart of this point. (19)

Application of technique: this point is referring to professional dancers being tired or fatigued during tour or performance periods. In periods like that it is typical for the dancers to be exhausted and thereby not being able to focus correctly and dance with correct technique. This may also include bad choreography. In the later years the strive for new and "different" choreography has lead to a trend where almost impossible steps and tricks have been included to performances. (19)

Environmental: these factors involve floor construction and temperature. Even though these factors mostly contribute to dance related injuries, they may be a factor in true dance injuries as well. (19) For more on floors see chapter 7.1.

Solomon et al. (20) state in their book on injury prevention that most injuries occur in the form of a bad circle originating in faulty movement patterns. They state a unprepared body trying to deal with heavy technique or choreography tend to develop faulty patterns, this again manifesting itself in improper muscle sequencing, misfiring of unneeded muscles, overuse of certain muscles and muscle tone imbalances. With the overall repetition often found in dance this all makes up for all the ingredients of injury development.

2.2.2 Technical faults

As just mentioned; technical faults are looked upon as the main cause of injury in dancers when reviewing literature. For the best prevention of all injuries I believe that technical correction should be an essential part of all dance classes. The most important difference between a good and a bad dance teacher is the ability to see the students small faults and correct them properly (19), but the shortness of classes of the pressure for progression and performance usual prevents the teacher in having time to correct all students at all times.

Hamilton et.al (12) states that "*Although most young dance students have acquired basic motor skills, many of them learn dance-specific skills before they have achieved a mature understanding of these basic techniques. As a result, immature patterns are being carried into dance training and may become a habitual part of the student`s skill in performing dance-specific patterns. The resulting compensations can lead to many of the dysfunctional technique patterns that cause injuries seen in the more mature dancer as well as in the student.* "

Usually a technical fault is not isolated and alone. Most faults are accompanied with other faults, and the careful assessment of the whole dancer is necessary (19).

Following is a list of the most frequent technical faults, concerning the lower extremities (19).

- *Lordosis*; usually due to muscle weakness, overturning of the feet, or hip flexor tightness.
- *Over turning* of the feet; see part 1.3.3
- *Restriction of turn out* from hips; by anatomical limitations or ligamental tightness.
- *Sway back knees*; usually do to Vastus Medialis weakness, and overly eager student wanting to have "nice lines".
- *Rolling in* of feet; see part 6.4.
- *Incorrect weight bearing*; usually due to overturning, lordosis, and muscle weakness and imbalance.

Another frequent finding amongst dancers is a classical muscle imbalances related to faulty turn-out. Due to many dancers "not perfect" turn-out they tend to compensate in different ways. Often you will see favoring stretching the adductors and other medial structures, ignoring abductors of hip and thigh. In addition the dance training usually leaves the abductors strong and adductors weak. This imbalance often leads to patellar tracing and other injuries, especially of knee. (8).

Faults of the upper body may also affect the lower extremity. These include, amongst others, incorrect holding of the arms accompanied with tightness in arms and neck, shoulder discrepancy due to environmental factors and faulty posture, and scoliosis (19)

I will now describe to more detail the two most frequently seen technical faults; turn out and rolling in of feet.

2.2.3 Turn-out

As I mentioned previously turn out is probably the most important position and special consideration in a dancer, especially classically trained dancers. This position of external rotation is unique to dance and many authors hold it to be the most important requirement of ballet (20). Frequently being done with errors (19) (22) (28) (32) it is one of the most important aspects of injury prevention, and the improper turn out results in excessive stress on both back, hip, knee and foot leading to injury (18) (20) (26) (40). Few dancers are able to achieve the "perfect" turn out but strives to achieve it. I will in this chapter describe reasons

for limited turn out and also the consequences of improper turn out. Improvement of turn out will be discussed later.

Restriction of turn out, or complaint of a "small turn out", is frequently seen amongst dancers and dance teachers. Turn-out is influenced by anatomical structures, ligaments, tendons, capsule, strength and length of muscles (20).

Anatomical restrictions are absolute and cannot be altered by stretching or exercise (19). They include the depth, shape and orientation of the acetabulum and the angle of the neck of femur relative to the shaft (19) (20). Femoral neck anteversion is commonly associated with toeing in, whilst femoral neck retroversion is associated with toeing out, and will allow a greater extent of external rotation (20) ;thus making the retroversion more desirable for dancers. Femoral neck anteversion is found in most young children and at birth it is estimated to be 30 to 50 degrees (54). During normal development the anteversion gradually decreases (18) (20) (54) and in the adult skeleton there is an average of 8 degrees anteversion left (20).
It is commonly believed that children starting ballet training at a young age can to a large extent change their skeletal structures and thereby decrease the anatomical restrictions. Children starting before the age of 11 may be able to alter the actual angle of the femoral neck, thus improving turn out (9) (20).

Soft-structure restrictions may be altered also after the age of 11. The soft structures affecting turn out include capsule, ligaments, tendons and muscles. Improvements of turn out in the mature dancer is most likely limited to changes in these structures (18), and then to a lesser extent the ligaments and capsule, compared to muscles (20).
Surrounding the hip are various ligaments and the joint capsule, and tightness in these structures will limit the turn out. Even though these structures are extremely difficult to stretch, especially after puberty, it is possible (19).
Fibrous tissues like ligaments and capsules are difficult to stretch once mature. The most important ligament for the dancer is the illiofemoral ligament, limiting the ability of the femur to externally rotate and also limiting the extension (18) (20).
The muscles producing a restriction through being tight are quite easy to change compared to the ligaments. Through stretching one can improve the range of motion to external rotation, and especially important is stretching of internal rotators of hip, hamstrings, hip adductors and hip flexors, with internal rotators having the most direct effect on turn-out (20).

Muscle weakness is also a factor in the restrictions to turn-out. This is typically shown when examining the range of motion in the hip finding that the dancer has greater range of motion then she/he is able to use during dancing. This is a sign that the dancer is not able to utilize force or muscle coordination to control the turn-out (20).

In dance most of the focus on muscles should be held to the deep external rotators (20); Piriformis, Gemmeli, Obturators and Quadratus Femoris (55). These produce external rotation at the hip with minimal secondary actions. Muscles that may help to externally rotate the hip include Gluteus Maximus, Gluteus Medius and Sartorius, but these also have other actions.
For a dancer it is important to be able to differentiate the deep rotators from the helping muscles to exclude the secondary actions of these muscles. For example the Gluteus Maximus, in addition to external rotation, produces hip extension. When a dancers is doing a front *attitude*, meaning hip flexion with external rotation, the function of hip extension will produce an undesired opposite action to the *attitude*, thus limiting the movement. In the same manner the Gluteus Medius and Sartorius, which produce hip abduction with the external rotation, will affect movements to adduction. This is a common problem in dance and is usually referred to as "lifting the hip", which is considered very undesirable (20).

From my own experience as both dance teacher and dancer I know that the use of improper muscles or bad muscle coordination leads to many problems in dance; both technical and health related.
Recently I was observing dance students at Langhaugen High School of Dance in Norway, where I found this problem in almost all the students there. Many of them expressed that they were troubled by "*limited movements*", meaning they were unhappy about their ability to maintain or achieve full range of motion in the different dance positions, as for example *attitude*. I believe that most of them are, as mentioned here, using the wrong muscles for holding their turn out, thus "blocking" the joints and preventing the full range of motion. Few of them seemed to be in control of their deep muscles, and thus using mostly large superficial muscles. I could see all of them using their Gluteus Maximus to a large extent during almost all exercises, especially exercises including lifting of one leg from the floor. Also many of them lifted their hip when weigh needed to be held on one leg, perfectly illustrating the statements from previously in this chapter.

In my opinion it is extremely difficult for young dancers to localize these muscles, not to mention use them. Very seldom you can see the use of specific exercises to help them locate them or to strengthen them, and I don't find it strange that the larger muscle groups are used to maintain the turn out. Comments I have experienced being used to locate them are; "pull your inner thighs outwards", and "squeeze the lower buttocks". Dance teachers in general don't have the knowledge or opportunity to give their students specific exercises for improving these types of faulty muscle coordination.
When I spoke to the students of the class I was told that none of them could actively contract the deep hip muscles. None of them could honestly admit to knowing how they were to be used, and almost all told me that when turning out they mostly felt a contraction in their Gluteus Maximus and on the lateral and front of their hips. I find it quite depressing that these students are at this quite high level of ballet, and yet have not been properly instructed in how to keep this fundamental position without putting themselves in a position not being able to use their full potential and also in a position to get injured.
I believe that education in basic Anatomy and Kinesiology is fundamental for achieving the proper muscle control. By knowledge of muscles and their insertions and actions you can more easily use visualization to get in contact with these muscles. I also believe that specific exercises for strengthening the deep muscles are necessary, and this is also supported by the statement from Clippinger (20) that most dancers can improve their turn out by 15-30 degrees through strengthening of the deep outward rotators. I will describe more about this in the later parts of this thesis, regarding prevention.

As mentioned in the beginning of this chapter turn out problems are one of the most frequent causes for injuries to the lower extremity (18) (19) (26), and also interfere largely with skill development (20). This improper turn out can also be called "screwing the knees" and it leads to an extreme torsion in the knee (8) (20), increasing the risk for injury. Many dancers actively use a "false turn out" or force their turn out without being aware of the consequences of these actions.

Consequences of over-turning include; rolling in of feet/pronation of feet, maladaptive postures, injuries to first metatarsophalangeal joint, clawing of the toes, degenerative disorders, weakness of intrinsic foot muscles, stress fractures, medial knee injuries, decreased strength and anterior compartment syndrome (18) (19).

Because the knee is a modified hinge joint rather than a true hinge joint you can achieve 40-50 degrees of external rotation of the tibia if the knees are flexed, like mentioned previously. Hence, it is easy to bring the heels more forward when the knees are bent, in for example a pliè. This is frequently seen in dancers, and even though it produces an increased turn out of the feet it gives extreme torsion stress in knees when they are straightened. This also alters the rest of the body and can contribute to injuries in spine, hip, shin, ankle and foot (20).

A common pattern often seen is forced turn out, pronated feet, hyper-extended knees, anterior pelvic tilt and flaring ribs. This pattern not only leads to injury, but also prevents skill development as the development of adequate strength and muscle activation patterns is hindered (18) (20).

Several authors express the importance of evaluating turn out when assessing the dancer for diagnostic purposes. As mentioned previously Grossman (18), in her article on assessment of turn out, mentions how measurements of pure hip external rotation is insufficient when looking at turn-out as knee locking, tibial torsion and ankle also contributes. Usually an active standing measure in first position is preferred, observing the dancer for compensations and screwing of knees. Different devices have been made for this purpose (18). Another way of assessment can be done in the fifth position taking a "Plumb line" measurement from the midline of the patellae. This line should land over the second or third toe. If the line falls medially to the foot during a pliè the dancer is screwing the knee (1).

2.2.4 Rolling of Feet

Being one of the most frequent technical faults beside improper turn out, rolling inward on the foot is usually caused by muscle weakness of intrinsic foot muscles or over turning, and from a preventive point of view this foot pronation is very important (20).

Rolling in on the feet is a pronation in the subtalar joint that allows the Calcaneus to evert. As the Calcaneus everts it forces the talus to internally rotate and plantarflex. None of these three movements can occur alone (20).

Intrinsic muscles of the feet work to stabilize the foot during balancing, propulsion, walking and running, and also align all the small bones of the foot (56). They also ensure proper weigh distribution, move the toes and keep the arches of foot (19). Weakness of these muscles interferes with weight distribution and this may result in the weight being taken almost

entirely by the heel instead of being distributed evenly throughout the foot. When on pointè the weakness will lead to clawing of the toes and the dancer will have all weight on knuckles of toes. When landing from jumps the weight transfer will be fault leading to injuries to knees and shin (19).

Rolling in of the foot results in a weight back situation again leading to improper control of turn out as the foot position prevents the hip muscles to work properly. The same is true for the calf muscles, and these may be strained to the point of tendinitis. Especially Tibialis Posterior is prone for this situation. The rolling also leads to an excessive strain on the medial knee, and medial structures of ankle (19). The internal rotation in talus transfer's to the tibia causing internal rotation there, this often results in pulling of the patellar ligament internally, thus changing the position of the patella (20).
In the rolling in position most of the weight in taken on the medial aspects of foot, and especially the great toe. In the long run this situation can lead to sprains of the capsule, valgus position of the toe and eventually a Hallux Valgus deformity, and worst case scenario a stress fracture (19).
Solomon et al (20) states that a small amount of pronation is natural to absorb shock, but excessive pronation often lead to the common overuse injuries seen in dancers, as shin splints, plantar fasciitis and stress fractures.

In my opinion treatment of any issue in a dancer is impossible without taking these two main technical faults into consideration. If a dancer has any problems at all in any joint of the lower extremity I believe that improper turn out and/or rolling of the foot can be accounted to almost all issues the dancer face. In my experience both low back pain, hip problems, knee pains and ankle injuries can be traced back to faulty turn out and/or rolling of the foot. Without correction of the faulty technique all rehabilitation or treatment of the lower extremity will be useless, and strengthening of weakened muscles is essential for proper rehabilitation.

2.2.5 Knee Hyperextension

In dance, and especially in ballet, long lines are emphasized to reach the esthetic norm of the style. Hyperextended knees have been found to be very prevalent in dance, and especially in ballet (46). However, Howse (19) states that, it is not ballet training itself that causes hyperextended knees as previously thought, but possibly bad teachers encouraging it. He

further says that hyperextension is usually due to “loose joints” but that incorrect working may aggravate the situation. Teachers who do not teach the difference between pulling up in the knee and pushing back may contribute to development of a bad knee position (19) (46).

Hyperextended knees are also frequently called swayback knees, and can be as much as 20 degrees past neutral position (19).

There are several ways of prevention, and ways to improve, this situation of hyperextension. Simply stopping the extension before the hyper position is often enough to stop worsening of the situation. Encouraging students to pull up in the knee instead of pulling back is often helpful, and sometimes including a pull up of the backside just below knee may help as the hamstrings are included and a co-contraction occurs over the knee joint. Another approach can be to limit the internal rotation of femur. Internal rotation of femur is associated with the last degrees of knee extension, and focusing on limiting this may help some people to limit their hyperextension. (46). Hamstring strengthening and working on centering body weight, especially in pointè and demì pointè will often decrease the tendency toward hyperextension (20).

Relation to weak feet or faulty foot position is important to evaluate. Hyperextended knees often cause a “*weight-back situation”*, leading to several secondary issues, including lordosis (19).

For the dancer the knees will usually “feel bent” when trying to correct the hyperextension. Working with visual stimuli through a mirror, and continual repetition, might help to change this pattern (46).

3. Typical Injuries of Lower Extremity

As seen in the chapter of epidemiology the lower extremity is the most frequently injured area in dancers compared to other body parts.
Epidemiological studies on dance injuries are most frequently done trying to identify these specific "areas of injury" rather than the specific diagnosis and I have not been able to find any studies trying to identify which specific injuries/diagnosis are more frequent. I have for that reason based this chapter on the diagnosis that I frequently find mentioned in important text in the field of Dance Medicine, Sports Medicine and physiotherapy when dance injury is discussed. There is usually a broad agreement in the literature what are the most common injuries, however, most of this seems to be based on screening processes and experience from clinics and dance institutions.

I have only chosen injuries that are mentioned in the list of common injuries by *Harkness Center for Dance Injuries* (21), and in addition in *Essential Dance Medicine* by Ana Bracilovic (22), *Dance Technique and Injury Prevention* by Justin Howse (10) and *Preventing Dance Injuries* by Solomon et al. (11). These are all influential and important books, and institute, in the world of dance medicine, and since research and studies on this area lack, I have based these following chapters on findings and experiences of these authors.

In this part of the thesis I will review the common injuries of the hip, knee, foot and ankle, and go through epidemiology, etiology, clinical picture and treatment of them.

Solomon et al state in their book on injury prevention in dance (20);

"It is our belief that the prevention of injuries properly originates in a clear understanding of the what, where, when and how of their occurrence"

3.1 Hip Injuries

The hip is very important in dance, as it is the main area for the characteristic turn out, and also as it is the most visible joint when on stage. Controlling both hip and turn out is essential to having balance between trunk and lower extremity for correct technique (38).

When reviewing literature on dance injury I find it clear that hip injury is not as common in dancers as with injury to other joints of the lower extremity, at least it has not been researched as frequent as other injuries. Most papers focus more on injury to feet, ankles and knees. However, in my experience hip *"issues*" are very common. During my own dance training and through my practices at the dance conservatory in Norway I learned that controlling muscles around the hip, maintaining a balanced pelvis and having proper technical skills concerning the hip is of great concern to dance students. So, maybe the main concern of the hips is not injury, but muscle imbalances and poor muscle control? I will however review the injuries that do tend to occur as common to dancers in literature.

Epidemiologically hip injuries have also been found to be less common. In a review published in the Journal of Dance Medicine & Science (38) the author states that researchers have found hip injury to be from 6-14% of injuries occurring in dancers of ballet companies. The studies he reviewed are all long term (over several years). He does state however that smaller problems as muscle strains of hamstrings and adductors are common amongst dancers.

3.1.1 Snapping Hip Syndrome and Illiopsoas Tendinitis

These conditions are considered a common dance injury by the following citations;
(20) (22) (26) (38) (46) (51) (57)

While reading about Snapping Hip Syndrome and Illiopsoas Tendinitis I was surprised about the common confusion, or disagreement, that seemed to be present in literature at my first view. Some authors tend to use the two terms separately, others use them for the same injury, and some use them as different stages o f the same injury. However, in newer research there seems to be a general agreement that the two conditions are highly connected to each other. I have therefore decided to leave the otherwise used structure and discuss these two conditions together.

Snapping Hip Syndrome (coxa saltans) is a very common phenomenon in dancers (20) (26) (46), especially young (38) female ballet dancers (22). It generally remains asymptomatic (20), often resulting in ignoring of the condition (58).

The dancer often experiences a click or snapping sound in the hip, especially during *developpè à la secondè* (flexion, abduction, external rotation of hip) (22) (46). Often the click can be reproduced by the dancer on command, and it is usually painless (22).

Snapping Hip Syndrome has in the recent years been divided into two entities; external and internal snapping hip (20) (22) (46) (51) . Both considered an overuse injury (26) (58).

External, or lateral, snapping hip are thought to arise from Tensor Fascia Latae, Illiotibial Band or Gluteus Maximus sliding over the Greater Trochanter of the Femur (22) (58). This type of snapping hip is often associated with landing from leaps and *ronds dè jambe* exercises when the muscles mentioned are working to stabilize the hip (38). The dancer will often in these cases explain that it feels like the hip is sliding out of its place (38) (46) (58). The external snapping hip is usual less painful then internal snapping hip (22).
Factors suggested to be contributing to development of external snapping hip include a wide pelvis, prominent trochanter, ligamental laxity, weakness of hip abductors, “sitting” in the hip, and tightness of Illiotibial Band (46). All these factors are, by Clippinger (46), collected from different studies done on both runners and dancers. These studies are not accessible for me, but she states that in dancers the Illiotibial Band tightness and associated low values of hip adduction has a high prevalence in these studies. She suggests that treatment of external snapping hip to include stretching of Illiotibial Band and abductors and strengthening of the

hip abductors. Clippinger also states that in her experience the snapping often occurs when the dancer excessively shifts the pelvis laterally relative to the supporting leg and fails to maintain turn out of the supporting leg. Hence strengthening of external rotators of hip may also improve the situation.

Internal, or medial, snapping hip is usually involving the Illiopsoas tendon snapping over the head of femur, illiopectineal eminence, femoral head, femoral neck or lesser trochanter, depending on the author (20) (22) (46) (58). It is most often associated with movements as a *developpè a la secondè,* hence hip flexion, abduction and external rotation (22) (38) (58).
Usually internal snapping is more painful then external snapping (20)(22) and the pain is often located deep inside the groin (58). An internal snapping is often more severe for the dancer as the pain is more intense, hence being more limiting (20).
Solomon et al. (20) suggest that this internal snapping is highly connected to Illiopsoas tendinitis, and several other authors agree that the internal snapping often leads to an inflammation of the Illiopsoas tendon, including Bracilovic (22), and that this is most likely the reason for the snapping to be painful. Hence, the snapping itself not being painful but the repeated movements, often together with faulty biomechanics of hips and pelvis, leads to overloading or microtrauma of the tendon and thereby the inflammation and pain.
Solomon et al. states the following;
"Repeated loading of the Illiopsoas with many ballet movements results in a progressively stronger, but also tighter Illiopsoas muscles-tendon unit. This tightening may be further enhanced by lumbar lordosis, since the Illiopsoas takes its origin from the front of the lumbar spine. A third factor is that stretching of this muscle-tendon is very difficult to do on one`s own, and even with professional supervision and assistance is not easily accomplished. The end result is a tightened muscle-tendon complex in which the tendon begins to snap femur head as the leg is flexed at the hip, sometimes causing inflammation of the illiopectineal bursa. A number of early observers have implicated this as the primary source of pain."
In her book Bracilovic (22) also uses similar terms to describe development of Illiopsoas Tendinitis, and also states how this usually starts with a painless snapping hip.

In both external and internal snapping hip one can by palpation often find tenderness on the involved tendon (22) (58), thus helping to locate the problem.

When discussing treatment of Snapping Hip Syndrome all authors agree that treatment is totally dependent on symptomatology of the patient and that it usually involves exercises and treatment goaled to improve hip and pelvis mechanics; meaning a program including stretching and strengthening of hip and pelvis musculature mainly to maintain muscular balance and to have optimal stabilization and control (20) (22) (46).
Bracilovic (22) recommends the following;

- Anti-lordotic exercises, core strengthening, lumbo-pelvic stability exercises, peri-pelvic stretching and strengthening.
- Stretching of hip flexors, hip abductors, and hip external rotators.

In addition to this non-steroidal anti-inflammatory drugs can be useful for some patients and means as ultrasound can be helpful in the acute phases (58). Rest and stop of training for some time can be recommended in the patients with intense pain (22).

When the patient is examined for snapping hip one of the main differential considerations is as mentioned Illiopsoas Tendinitis.

Illiopsoas Tendinitis is, as previously mentioned, by many viewed upon as the source of pain in internal snapping hip syndrome. Usually when describing a patient that complains of Illiopsoas tendinitis the symptoms have started with an internal snapping hip that progressively became more and more painful over time eventually limiting possibilities to dance. The pain and snapping sound is typically worse with *developpè a la secondè* and *rond de jambe* (20) (22). Pain is usually palpable in Illiopsoas in the femoral triangle, bordered superiorly by the inguinal ligament, laterally by the Sartorius and medially by the Adductor Longus. In addition the patient usually has tight hip flexors (22).

Solomon et al. (20) state that they have fund three simple diagnostic tests to be proven helpful in diagnosis Illiopsoas Tendinitis;

1. *Provocative hyperflexion test* where the hip is slowly and progressively flexed by examiner while patient is relaxed supine on table. They found this to be painful in all encountered cases of Illiopsoas Tendinitis, and not painful in the uninvolved side.
2. *Frog position test* where one leg is flexed in knee, externally rotated and abducted on the table the patient is asked to adduct and flex against resistance. This was found to be painful when tendinitis was present.

3. *Internal rotation test* where leg is extended and abducted with lower leg hanging over the edge of table with knee flexed to 90 degrees. Slowly the leg is put o internal rotation. This has been found to put stress on the Illiopsoas unit with its associated bursa and therefore producing pain if tendinitis is present.

Treatment of Illiopsoas Tendinitis is similar to treatment of snapping hip.
Solomon et al. recommends the following and states they have had good effects with this approach to the condition;

- Relative rest and anti-inflammatory medications.
- Anti-lordotic exercises, peri-pelvic stretch and strengthening. Especially Illiopsoas stretches both for immediate relief but also to correct the biomechanical problems that caused the problem in the first place.
- Stretch and strength for hip external rotators, adductors and internal rotators should also be added.

These recommendations are very similar to recommendations by Bracilovic (22), and she adds that dancers with foot pronation need to also address this problem as it influences the whole mechanical chain of the foot.

After the dancer has been rehabilitated Solomon et al. (20) states that it is very important to explain to the dancer why this injury occurred and how to prevent development of new inflammations. They express that from their experience many ignore the snapping hip until the inflammation has developed, making the rehabilitation process and need for rest longer than necessary. They advice preventive means to be taken regarding snapping hips, meaning high technical correction to avoid the biomechanical changes that lead to the snapping and further the tendinitis.

3.1.2 Trochanteric Bursitis

This condition is considered a common dance injury by the following citations;
(22) (46) (51)

Trochanteric bursa lies over the greater trochanter and beneath the Illiotibial Band (46). The condition may also be called Greater Trochanter Pain Syndrome in some literature.

Epidemiology

Trochanteric bursitis is a common cause of hip pain in dancers (22). It occurs four times more frequent in females than in men, possibly due to differences in lower extremity biomechanics between the sexes (59).

Etiology

Trochanteric Bursitis is generally thought to either be from trauma or overuse, or as a complication from hip surgery.

Traumatic development is usually due to falling directly on the hip, and due to the bursa's superficial placement it is prone for this type of injury (59) (60) (61).

Overuse bursitis is however more common in dancers (22), resulting from repetitive microtrauma to the soft structures around the greater trochanter (59), often believed to be mostly due to poor biomechanical alignment (22) (46) (60).
Factors believed to cause this microtrauma include;

- Weakness of hip external rotators and abductors (46) (59)
- Tightness of Illiotibial band (46) (59) (60) (61)
- Leg length discrepancies (22) (46) (59) (60)
- Increased collum anteversion (60)
- Broad pelvis (46) (60)
- Over-pronation of foot with compensatory internal rotation of tibia (46) (60)
- Alteration of gait patterns due to back pain (59)
- Gluteal tendon degeneration or tears at the trochanter insertion (59)
- Obesity or arthritis (59)

In addition to these causes some authors state that patients with Trochanteric Bursitis may often present with additional diagnoses as scoliosis, snapping hip syndrome, lumbosacral radiculopathy or sacroiliac disturbances (22) (46) (61).

Clinical picture

Classically the patient presents with localized pain on lateral side of hip by the trochanter. The pain is usually worse during the night and when sleeping on the affected hip. The pain may keep the patient up at night. Radiation of the pain down the lateral thigh is common, mimicking sciatica, but should not continue over the knee joint toward the foot. Paresthesia may be present but without link to any specific dermatome. (22) (59) (60) (61).

Typically the patient express that pain is worsened when going from sitting position to standing, standing or walking for a long time or ascending stairs (22) (59).

Examinations

By palpation one may find tenderness and possible crepitus and swelling around the greater trochanter. In addition hip external rotation and abduction range of motion test will usually reveal pain and possibly decreased movements. Resisted abduction will usually be painful. (22) (46) (59) (61).

Frontera et al. (59) also states that Trendelenburg Sign is helpful in diagnosis Trochanteric Bursitis. The test will usually be positive when weight bearing on the affected side as the patient is not able to optimally use Gluteus Medius and Minimus due to the inflammation, hence not being able to properly stabilize the hip. They state that you will usually see a drop of the contralateral hip with a compensatory shift of trunk to affected side. Clippinger also agrees with this (46).

For differential diagnosis osteoarthritis of the hip is important. Pain in internal rotation, largely limited movements of hip and groin pain being the important red flags (59) (61).
Radiographic imaging can be helpful if other pathologies are suspected (22) (59).

A full examination should be done to identify etiology of the bursitis.

Treatment

In acute phases relative rest is recommended, meaning avoiding painful movements and situations and limiting exercises, often accompanied by anti-inflammatory drugs. Some authors also recommend injections of corticosteroids.
(22) (46) (59) (60) (61)

At the onset of injury ice massage and ionothoporesis may be beneficial (59).
Clippinger (46) states that heat application prior to dance class and ice after dance class may be helpful.

Rehabilitation should focus on stretching and strengthening to obtain optimal function of hip and pelvis combined with correction of biomechanical malalignment.
In recommendations one especially finds the following:

- Stretching Illiotibial Band (22) (46) (59) (60) (61)
- Stretching Tensor Fascia Latae (22) (59) (60) (61)
- Stretching hip external rotators (22) (61)
- Stretching hip flexors (22) (61)
- Stretching quadriceps (22) (61)
- Strengthening of hip external rotators (59)
- Strengthening of hip abductors (46) (59)
- Ultrasound and TENS (22) (59) (61)
- Phonophoresis (59) (61)
- Treating leg length discrepancy or other biomechanical malalignment (22) (59) (60)
- Correction of technical faults and working on changing outcome of Trendelenburg Sign (46)

If this conservative treatment fails surgery is possible (22) (46) (59) (60) (61).

3.1.3 Other

As seen in the chapter of epidemiology hip injury is not as frequent as ankle and foot injuries, and for that reason there is also limited research and text regarding this.
In the literature I have studied the most commonly mentioned diagnoses are Snapping Hip Syndrome, Illiopsoas Tendonitis and Trochanteric Bursitis as mentioned previously in this text. However, some authors also state that Piriformis Syndrome and early onset Osteoarthritis is important to mention when dealing with dance injuries of the hip (20) (22), and I have therefore briefly reviewed the available literature.

Piriformis syndrome is found in the list of common injuries by Harkness (51) and also in the book by Bracilovic (22), however, the diagnosis does not seem to be especially related to dancers compared to general population, and is also mostly mentioned when dealing with low back pain. Nevertheless Piriformis Syndrome does seem important in my opinion when dealing with the dancer; Piriformis being one of the main external rotators of the hip. Harkness also states that Piriformis has a tendency to be thigh in dancers thus contributing to compression of the nerve.

According Bracilovic (22) the syndrome is characterized by pain in gluteal region and along the inervation of sciatic nerve. Hence, acting like sciatica. She states that it is often overdiagnosed, as it is similar to other problems of the gluteal region.

Etiology of the problem is highly discussed as there are many anatomical variations of the pathway of the sciatic nerve. But generally the syndrome is associated with the piriformis compressing the sciatic nerve in some way, either by trauma or spasm (20) (22) (59).

On examination one may find positive Straight Leg Raise. Pain may be reproduced by doing passive adduction and internal rotation of hip as it compresses the nerve, and by resisted contraction of the piriformis in external rotation and abduction you may find weakness and pain (22) (59).

Treatment of Piriformis syndrome is mainly stretching and relaxation of the piriformis possibly combined with strengthening of gluteus medius. Heat modalities may be added, as ultrasound, and in acute phase anti-inflammatory drugs may be used (22) (59).

Osteoarthritis is another diagnosis mentioned when dealing with the hip. According to Bracilovic this is a diagnosis mainly concerning older retired dancers, but she states that for them the osteoarthritis often occurs sooner than in the general population (22). Osteoarthritis is due to aging, joint overuse and previous injuries, and is treated in dancers as in general population (22) (59).

3.2 Knee Injuries

Although foot and ankle are stated as being the most common site of injury in dancers the knee also tends to be affected to a large degree. Jenkinson and Bolin (1), in their review article for the Journal of Dance Medicine & Science, state that they found the knee to be involved in 14-20% of all injuries in ballet, in modern the knee is affected 10.8-25% of the time, and in theatrical dance only 8%. Several of their review papers state that knee injuries may be secondary to foot and ankle problems (none of these articles are accessible to me).

They also state that usual complaints regarding the knee in dancers are due to faulty technique, especially concerning turn out. Screwing the knee and not respecting anatomical limitations produce a great increase in the medial stress on the knee.

3.2.1 Patellofemoral Pain

This is considered a common dance injury by the following citations;

(1) (20) (22) (26) (51) (57)

Epidemiology

Amongst dancers patellofemoral pain is a frequent complaint and it is responsible for a large percentage of the overall knee problems they encounter (1) (20) (22). For clinicians dealing with sports medicine this is also considered to be one of the most common problems (62).

Etiology

The mechanism of patellofemoral pain is not fully understood, but the term is generally used for anterior knee pain that occurs without any structural knee pathology (62) (63). There exists several theories on the pain development but there is a general agreement that it is usually multifactorial and involving faulty biomechanics of lower extremity (12) (20) (22) (63), giving the joint loads that it cannot handle. Jenkins and Bolin (1) are skeptics to the term patello-femoral syndrome, as they state this is a "wastebasket diagnosis" clinicians use when unable to properly diagnose. They state the large importance in differentiating anterior knee pain/patella-femoral pain syndrome from other diagnosis of the knee as patellar subluxations, bursitis, tendonitis, menisci or ligamental injury.

It is likely that the pain(in patella-femoral pain syndrome) arises from tension or compression of the soft structures surrounding the joint (63), and different patients will have individual specific areas of pain as it is suggested that many different structures can produce the pain (62). Research done by Dye et al. in 1998 (not accessible to me, but reviewed by Kolt (62)) found that different intra-articular structures were capable of producing pain signals to various degrees. They found that palpation of anterior synovium and fat pad elicited the greatest pain sensation, followed by medial and lateral retinacula, tibial and femoral insertions of anterior cruciate ligament and posterior cruciate ligament, then the middle regions of the two ligaments, the capsular margins of the menisci, and the articular cartilage surfaces.

Solomon et al. (20) mention the following as causes for pain to occur;

- Lower extremity malalignment with increased femoral anteversion, tibial torsion and foot pronation.
- Poor technique and overuse leading to overload of patella due to high frequency of knee flexion and improper use of quadriceps during pliè. A constant quadriceps contraction during pliè gives constant high compressions forces to the joint.

- Screwing the knee to gain more turn out using the Illiotibial Band. This will pull patella laterally and give large compression forces during pliè.
- Tightness of Illiotibial band in general.

Bracilovic (22) agrees to these etiologies and states that from her experience poor core muscle control also is a contributing factor for many. This poor control often leads to increased anterior pelvic tilt, further femoral internal rotation, tibial external rotation and foot pronation as compensatory mechanisms. With the internal rotation of femur one loses control of Gluteals and hamstrings.

Determining the exact source of the pain is demanding and requires thorough history and examinations (20), and for proper rehabilitation all malalignments need to be addressed and removed.

Clinical picture

Typically the dancer will present with poorly localized anterior knee pain that is worse during pliè, climbing stairs, running and with knee flexion in general, like with prolonged sitting. Feelings of the knee "giving away", usually due to reflexive quadriceps inhibition is normal as well as the knee "catching" or being stiff. Usually the problem has both a gradual onset and progression. (20) (22).

Examination

As this diagnosis is quite diffuse, more of an umbrella term, the examination is very important to be able to treat the injury properly. As the most common cause of pain is mechanical malalignment the individual's personal postural faults can be the only way to remove the pain. Recommendations for examinations include;

- Complete history of the problem with full description of pain, onset and specific painful situations etc.
- Postural observation with focus to biomechanical alignment of pelvis and lower extremity.
- Palpation to locate exact area of the pain and identify if swelling is present
- Functional and dynamic testing to see muscle function and coordination, joint movements, and especially patellar movements during knee flexion and extension.
- In dancers technique should be evaluated, especially lower extremity position during turn out and pliè. (22) (62) (63).

Treatment

Treatment of patellofemoral pain needs to be highly individual as both etiology and symptoms may vary from person to person. Treatment is aimed at pain relieve and correction of mechanical faults.

Conservative treatment is usually very successful when involving the basic concepts of core strengthening and quadriceps training. Researchers have concluded that simple quadriceps exercises in closed chain have been proven most effective as this facilitates correct movement of patella. Kolt et al (62) reviews an extensive amount of research on the topic, and findings show that even though Vastus Medialis is often the targeted muscle, isolation is quite difficult. For that reason slowly performed closed chain exercises within the inner range (30-0 degrees) of quadriceps are usually recommended (62) (63).

In dance medicine literature the following recommendations are used;

- Initial relative rest
- Stretching Illiotibial band and strengthening Vastus Medialis to obtain correct patellar position is often helpful when lateral deviation of patella is found. In dancers Solomon et al (20) states that this is usually cause of the problem and therefore very effective.
- Technique correction if faults are noted in examination
- Strengthening of core musculature and balancing all joints of extremities
- If hyperextension is found stretching of quadriceps combined with strengthening hamstrings are recommended to obtain more muscular balance around the knee to minimize hyperextension and thereby limiting stress to knee.
- Teaching to initiate pliè using external rotators and ending pliè by adductors, minimizing quadriceps activity. (20) (22).

3.2.2 Patellar Tendinitis

This is considered a common dance injury by the following citations;
(12) (20) (22) (23) (51) (64)

Epidemiology

According to Solomon et al. (20) researchers have found that patellar tendinitis accounts for 16% of all knee problems in professional ballet dancers. The condition is also often referred to as jumper`s knee (20)(22). It is generally viewed upon as very common in athletes performing jumps, running and squatting (pliè) repeatedly (12) (26) (65). Patellar tendonitis is often seen in male ballet dancers, often performing frequent jumps (1).

Etiology

Patellar tendinitis normally presents as an overuse or overload injury of the knee`s extensor mechanism (1) (26) (64) , commonly due to poor training or technique (20) (26).
The forceful contraction of quadriceps during jumping and the subsequent eccentric contraction of it during landing puts great stress on the patellar tendon, often causing the inflammation (22) (64). Hard surfaces or poor footwear have also been stated to contribute to the condition (23) (26). Dancers cheating with turn-out are also predisposed to develop tendinitis due to excessive load on the patellar tendon due to increased torsional stress (23).

Clinical Picture

Patients typically present with anterior knee pain and the pain can usually be palpated at the inferior pole of the patella in the midline of the tendon (22) (26) (64) (65). The patient may describe the pain as aching and/or dull (22), and often worsened or triggered by activity of quadriceps (20) (65).

Examination

Several of my sources use a classification system of patellar tendinitis developed by Blazina et al. in 1973 (22) (26) (64).
This system divides the condition into 4 stages (26);

1. Pain after continued physical activity that resolves with rest, but no functional impairment.

2. Pain at beginning and end of activity, but the athlete is still performing normally.
3. Pain is present during training and the athlete is experiencing problems with performing at satisfactory level.
4. Unable to perform sports at satisfactory level.

Some differences in the classification can be found throughout literature and the Blazina stages have been modified by several authors.

Palpation will reveal point tenderness on inferior parts of the patella. Tenderness above patella indicates quadriceps insertion tendinitis (22).
Extending knee against resistance will normally provoke pain, usually in the ranges 30-0 degrees (22), and also flexing of knee beyond 120 degrees (20).

Active range of motion is usually in full range (22).

Diagnosis can also be made through high frequency ultrasound, showing an abnormal tendon (22) (26). MRI and CT can also be helpful (26).

Treatment

The use of RICE principle, cease of training and non-steroidal anti-inflammatories are the first ways of treatment to decrease inflammation (12) (20) (22) (64) (65). Following the decrease of inflammation further rehabilitation should aim at decreasing the pain and restoring strength, flexibility, range of motion and balance of quadriceps mechanisms. The following have been stated to be effective;

- General reeducation of alignment (12)
- Ionothoporesis (26) (64)
- Ultrasound (22) (26) (65)
- Stretching of quadriceps (12) (22)
- Strengthening quadriceps eccentrically on decline board (squat) (20) (22) (23) (26)
- Friction massage (64) (65)
- Brace (22) (26) (65)
- Pilates method (12)

Surgical treatment is only advised if all conservative means have failed, and it is rarely needed (26) (64).

3.2.3 Meniscus Tears

This is considered a common dance injury by the following citations;
(19) (20)(22) (23) (46) (51)

Epidemiology

Medial menisci are more frequently injured compared to lateral menisci (20) (46) (65) (66). However, lateral tears are more common in dancers then in other athletes (8) (19). Tears may occur alone or together with ligamental damage, and Bahr and Maehlum (60) states that 75% of patients with anterior cruciate ligament injury sustain a simultaneous menisci injury. Considered to be a common dance injury as a result of increased flexion and torque at the knee (22).

Etiology

The menisci work as shock absorbers and stabilizers of the knee joint (60), hence an injury may in the longer run affect these functions on the knee. They are located between the femoral condyle and the tibial plateau (57), and they allow the femur and tibia to articulate without pain (65). Most commonly the menisci are damaged through forced rotation or twisting of the knee, often together with a valgus stress and either a hyperextension or hyperflexion mechanism (8) (46) (65).

In dancers the meniscus tears are usually resulting from attempts to increase turn-out by "screwing" the knee (8) (20) (22) (23) (46). This means the dancer takes advantage of the knee laxity during flexion and turns out from the ground up, instead of turning from the hip down. In dance the menisci are especially vulnerable when in grand pliè (especially lateral menisci), during landing from jumps and when trying to improve turn out (20) (22). These types of injuries are considered chronic and as "wear and tear" injuries. Acute/traumatic injuries to the menisci are usually a result of an accident or fall, for example when landing from a jump. Landing incorrectly from a jump with valgus stress to the knee may cause a medial damage. This is then often accompanied with internally rotated femur and flexed knee with foot on floor. Lateral damage is often when landing from jumps with varus stress, externally rotated femur with hyperflexion of knee, as in specific types of folk dancing (20) (22) (23).

Other causes of injuries include general imbalance of muscles of thigh, often meaning weakness of adductors and Vastus Medialis producing an increased lateral pulling in the knee.

This again combined with over turning and often rolling in of feet and possibly hyperextension of knee, produces increased and damaging stress of the knee (8)(19). Karageanes (67) states that dancers with anterior knee pain syndromes and medial meniscus tears avoid full knee extension and thereby a rapid atrophy of Vastus Medialis Obliqus develops. This increased lateral-medial quadriceps imbalance leads to an increased lateral pull and exacerbated patellofemoral incongruity. Solomon et.al (20) states that a previous anterior cruciate ligament injury may contribute to meniscus tears as it gives increased knee rotatory instability.

Clinical picture

The dancer will normally present with localized knee pain at the joint line, either medially or laterally at the knee joint depending on injury, often with localized swelling (20) (65). As the injury often is from overuse and poor technique in dancers the swelling can be delayed, or occur on several occasions. The same is for pain (8). Locking of the joint and a popping sound may be stated (8) (20) (57). Medial tears usually give more symptoms compared to lateral injuries (64), however, lateral injuries are often said to be more serious as the lateral menisci are more important in joint stability (60). Inability to flex or extend the knee is often present (20) (22) (65).

Examination

Meniscus tears can often be diagnosed based on medical history alone (8).

Palpation will often reveal tenderness around joint line of the involved parts, either medial or lateral (8) (22) (57) (65), and atrophy of the quadriceps if the injury is more than one week old (20) (22). Range of motion will typically be limited (20), deep squatting and hyperflexion will provoke pain, and in dancer jumps, pliè and developpè is usually a problem (22).

Test for ligamental instability should be done to exclude involvement of associated injuries (22).

Specific tests to provoke pain and diagnose involvement of menisci injury include;

- McMurray (8) (22) (57) (65) (66)
- Apley compression test (22) (57) (65) (66)
- Bounce home test (65)
- Payr Test (66).

The Apley distraction test can be used to differentiate from ligament involvement (22).

Differential diagnosis of meniscus tears include; (57) (64)

- Patellofemoral syndrome
- Synovial plica
- Loose body
- Ligamental injury
- Chondral fracture
- Patellar inflammation or dislocation
- Fat pad inflammation
- Synovitis
- Arthritis

For complete diagnosis, and deciding if to use conservative treatment or surgery, you need to do MRI imaging (22) (60).

Treatment

Immediate actions are to stop any training or activity, put ice to the knee, and if needed use crutches and non-steroidal anti-inflammatory drugs (22)(64). Prevention of atrophy and weakness should be started as soon as possible and sitting quadriceps exercises are useful (20) (64). Usually these conservative means are taken firstly, and if pain, swelling and locking does not reside in 4-6 weeks doctor should be consulted and usually surgery is indicated (19) (20) (22). Small tears that don't transverse the whole menisci may heal properly without surgery (60).

If injury does not require surgery gradual increase of activity is recommended, with focus on regaining range of motion and strength and obtaining a balanced knee joint (8) (20), especially concerning balance of adductors and abductors of hip. Modification of dance activity should be individualized dependent on the extent of the injury (22). If technical faults as screwing the knee contributed to the injury these faults must be removed prior to returning to dance training (8) (20). Solomon et.al (20) recommends doing barrè exercises supine on floor to relearn proper lower limb technique. They also encourage strengthening deep external rotators of hip to have better control of turn out, abdominal muscle strengthening and stretching of hip flexors to control pelvis and thereby decrease torque on the knee.

Neuromuscular training and proprioception must not be overlooked in rehabilitation and prevention, as it decreases rate of injury by increasing the dancer's awareness of body positions (8). When discussing knee injuries Scioscia et.al (8) recommends something they call transition classes. This is described as dance classes where physical therapist and dance teacher together have made a dance class containing both therapeutic exercises and technical training, preventing the dancer from losing dance technique during rehabilitation and also preventing the dancer to leave rehabilitation program to soon. I personally have questions to the possibilities of practical execution of this.

Surgery is indicated by doctor if tear is of a large extent (60) or if symptoms don`t disappear within 4-6 weeks (20) (22). Usually an arthroscopic technique is used (22) (60) (64). Dancers will usually be able to return to full training 6-8 weeks post-operatively (22).

3.3 Foot and Ankle Injuries

The ankle is a very important joint in dance, and ballet is unique in how it requires both maximal dorsiflexion (demì pliè) and maximal plantarflexion (en pointè) to gain proper technique (68). The ankle is also the most commonly injured body area in dance and various studies place the incidence of ankle injury between 4.7% and 22.2% of all injuries to dancers (68).

3.3.1 Hallux Valgus

This condition is viewed as a common dance injury by the following citations;
(4) (19) (22) (26) (27) (46) (51)

Hallux valgus is a condition with deviation of the big toe lateral to the midline accompanied with medial deviation of the first metatarsal head (69) (70) (71). The condition itself is not painful, but the bunion that often is produced may cause problems for the patient. The bunion, or callus, may be present at the metatarsal head and this is usually causing pain, tenderness and/or swelling (69). As the deformity increases secondary changes may occur in the joints of the toes creating further painful conditions, including metatarsalgia, subluxations and corns. More serious later development may lead to osteoarthritic changes (72).

Epidemiology:

Hallux valgus is the most common pathologic condition of the big toe (22), but specific epidemiological numbers are hard to find and there is a wide range of percentages made. A common agreement is that the condition is most prevalent in woman (69) (70), with a ratio of 9:1 when compared to men (73). It is more common in adults then in children (70), and considered to be a "common problem" in the general population (73) (74). Dancers typically presents with hallux valgus at a younger age then the normal population (22).

Etiology:

The development of the painful bunion starts with a slight angulation deformity in the metatarsophalangeal joint, the joint will be vulnerable for valgus pressures and cause valgus deformity of the hallux as well. Over time muscles as adductor hallucis and extensor hallucis longus will produce pulling forces on the hallux, and this again is resulting in a compensatory varus deformity of the metatarsal shaft, increasing the problem thus increasing the bunion. (71)

There are several factor believed to be involved in the etiology of the hallux valgus condition.

Genetics: heredity may play a role in the development, and there has been found increased incidents in families (69) (70). Some state that heredity is especially crucial in juvenile and adolescent hallux valgus, with as much as a 72% rate of maternal transmission (71).

Other conditions of feet: are believed to play a role. This including metatarsus primus varus, flatfoot deformity, hypermobility of the first ray, equines contractures (71), pronated hindfoot, neuromuscular disorders, Achilles contractures, (70), secondary to rheumatoid arthritis or osteoarthritis (69).

Gender: Women are seen to develop hallux valgus more often than men. There are several theories on why; one stating that females have smaller bones in general then men, also with a tendency towards more medial movements (71). This causing the adduction of the first metatarsal. Others believe that the difference in men and woman is solely due to the fact that woman wear different kinds of shoes, especially pointy high heels, that put excessive pressure on the hallux. (71)

Footwear: shoes are considered to play a major role in development of hallux valgus (70), and especially woman's shoes, which are narrow and with high heels, are mentioned as important factors (69) (74). Although hallux valgus occurs in populations that do not wear shoes, it is 15 times more prevalent in populations that do wear shoes and it is in this population we more frequently find the painful bunion (71). The theory of the importance of footwear in the development is primarily due to the major observations; the low prevalence in non-shoe wearing populations, the increasing prevalence in these populations after introducing shoes and the high prevalence of the condition in woman wearing high heel shoes with narrow toe box (73). The theory of high heeled shoes is not fully understood, but it is believed that the narrow shoes over longer time will put the toes in a faulty position and the toes are adapting to this position. When also a high heel is involved it is believed that the different weight bearing puts stress on the metatarsophalangeal joints and changes the kinematic chain (73).

Length and shape of the big toe: several studies have shown that people with hallux valgus have significantly longer first metatarsal compared to second metatarsal. It is believed that this difference will cause the toe to be compressed inside shoes and thereby cause a change in position (73). Some studies have tried to indentify a relation to development of hallux valgus and two different types of toe shapes; round and square. Research from 1981 concluded that rounded toes were predisposed for hallux valgus development, but later research had findings contrasting to these previous ones, leaving this theory still only a vague theory (73).

Muscle dysfunction: some authors believe that an imbalance between adductor hallucis and abductor hallucis longus can be a factor in development of hallux valgus. They believe that a weakened abductor may cause the adductor to pull on the toe. There have also been done electromyography studies where they have seen significantly less activity of the abductor in people with developed hallux valgus. But the direction of the relation cannot be stated with security (73)

Foot pronation: there seem to always have been drawn lines between foot pronation /flat feet and development of hallux valgus, but there have been few studies able to conclude with this, even though many patients with hallux valgus also often present with flat feet/pronated feet (73). It is believed that the high incident of hallux valgus in dancers are due to excessive pronation in feet when trying to achieve larger turn-out then joints can handle. Forcing external rotation in the hips and knees forces the subtalar joint to pronation in order to keep neutral position (22).

Clinical Picture:

Most people are without any symptoms. The ones presenting with symptoms often have major cosmetic concerns, and problems finding fitting shoes (70).The typical symptomatic patient may present with pain as the main problem, usually on medial aspects of feet and with accompanied complaints of lateral deviation of the big toe accompanied with the development of a bunion, or a "crooked foot" (22). Many patients also express increasing of pain when wearing thigh shoes, or during walking (73).

The most frequent pains are; (71)

- *Medial eminence pain* due to the head of the metatarsal being "uncovered", and this being compressed and irritated inside of shoes. There might be a irritation of the cutaneus nerves, and as the bunion appears there might be accompanying swelling and tenderness.
- *Pain at metatarsophalangeal joint* may occur as a result of changes inside the capsule of the joint. If there is progression of the disorder to osteoarthritic changes at the joint there might also occur stiffening of the joint accompanied with pain.
- *Transfer metatarsalgia* is a condition that is usually much more painful than the original hallux valgus condition. This occurs later in the development of the bunion, when the increased deformity leads to a transfer of loads to the second metatarsal

head. This again causing synovitis of this joint. The further progression involves the first metatarsal to finally move under the second toe, causing it to move dorsally and finally progress to a state of hammer or claw deformity due to the alterations in muscle balance. Now the toes are pushed dorsally causing the metatarsal heads to go in plantar direction, hence becoming overloaded and painful. This may also continue further along the row of toes, and in severe cases one can find subluxations as well (73) (72) .

Examination:

Examination should start with observation of the patient's foot, and usually further examinations are not required to diagnose hallux valgus (73).

Usual finding during aspection is the lateral toe deviation, often accompanied with hammertoe or claw deformity of the second toe due to "overcrowding", development of bunion that may or may not look inflamed with redness and swelling (73). Weight bearing might be changed and this again can be seen through changes in skin, often callus or corn formation under second metatarsal head, or you can see abnormal nails due to pressure inside shoes. (73)

Nevertheless other examinations can be done to determine severity and possible prognosis. Examination of gait and footwear is necessary to find compensatory walking pattern and possible improper footwear. Palpation may locate pain and thereby include or exclude nerve irritation (70) or involvement of inflammatory process (75). A manual exam can also detect crepitus, decreased range of motion or subluxations (70). The feet should also be observed in both sitting and standing, as the deformity will usually be accentuated in standing. In addition the feet should be examined for Pes Planus and pronation (74).

A dancer presenting with hallux valgus should be examined in the basic dance positions, as the development of the hallux often is due to faulty technique. Also evaluation of technique and limitations of mobility in jumps, relevè and pliè would be appropriate (22).

For more objective means a radiograph can be used, to see the hallux valgus angle (formed by proximal phalanx and first metatarsal). The radiography usually consists of lateral, AP and sesamoid views in weight-bearing position (22) (73) (74).

A normal hallux valgus angle is 15 degrees. Angles between 15 and 20 degrees are considered mild, between 20 and 40 degrees moderate, and above 40 degrees severe (74)

Treatment:

Treatment is initially conservative (74), including pain relief, addressing skin and nail conditions and means to stop progression and limit functional limitations (73).

Modification of shoes is very important, and correct shoes with wider toe box and softer material, or pads around bunion, can relieve pain in most patients (74). A widened toe box serves to minimize pressure on the medial eminence, and the shoes also need to be appropriately high to give place to the frequently seen deformities of the other toes. There are several over the counter products like pads, toe separators etc, but these have not been shown to change the deformity, but only relieve symptoms and to some extent stop progression (71).

Patients with Pes Planus and metatarsalgia may benefit from orthosis (71) (74), although they have not been found to stop progression (71). They should be soft and cushioned not hard, and custom made orthosis would sure its best purpose (71).

Patients should always be warned about the progression and means to stop it (70), and in ballet dancers the importance of changing their pointè shoes every 6-8 months, especially young and growing dancers, should be stressed (22).

Persistent pain after longer periods with conservative treatment is indications for surgery (74). Removing pain is the primary goal for surgery, making the foot "*shoe-able*" a secondary goal, but being able to wear "fashionable" shoes again is unrealistic (71). If correct surgery is chosen there have been excellent results reported, ranging from 75% to 90%, but 41% are never able to return to wearing desired shoes (70). There exist enormous amounts of different types of bunions and thereby over 100 different surgical procedures described in literature (71). Surgery should be considered the last resort (22), as it can result in postoperative restrictions in metatarsophalangeal joint, especially for athletes like dancers and sprinters (74). Surgery is also associated with high risk of reoccurrence (70), so underlying cause should be found and dealt with; whether it is biomechanical, in a dancer's technique or in the shoe wear of the patient.

3.3.2 Hallux Limitus/Rigidus

This condition is viewed as a common dance injury by the following citations;
(19) (22) (27) (51) (57)

Hallux Limitus and Hallux Rigidus are two terms used for the same condition, but the two names are usually describing a different state of the condition. Hallux Limitus is when the range of motion of the great toe is limited, and Hallux Rigidus is when the motion is lost completely, eventually with fusion of the joint (57) (73). Other names used to describe this condition include Hallux Flexus, Dorsal Bunion, Hallux Equines and Hallux Dolorosa (73) (76) (77).

Epidemiology

This condition has a long history, but in literature there are some variable times and names being used; First time being in 1881 by Nicoladoni (77) and later in 1887 by Davies Colley (77), they both called it Hallux Flexus. Also in 1887 the diagnosis was described by Cotterill (73), but using the name Hallux Rigidus.

No other condition of the great toe, except from Hallux Valgus, has received this much attention in medical texts and journals (76), and it is considered to be the second most common condition of the great toe (22). It is not largely studied, but there is a common agreement that the condition is more common in females, with a 1:2 ratio (22) (73). It has been stated to be common in female athlete of sports including jumping, running and also aerobic and ballet (57), and with an overall incidence rate of 1:40 in individuals over the age of 50 (22).

Etiology

Hallux Rigidus is an acquired arthritic condition that especially affects movement in the sagital plane (76). Few studies have been done to find a clear etiology of Hallux Rigidus, but it is commonly found to be of several different causes (73). The causes include anatomical issues as flat foot (76), narrow foot, pronated foot, abnormalities of hallux and metatarsus primus varus (77). Shoes, occupation, arthritic disorders and obesity have also associated with the condition, and genetics seem to also play a role (73). Some authors state that repeated trauma, as seen in many of the mentioned sports, also tend to lead to this condition (19) (57).

In dancers the common cause of developing this condition is believed to be forcing of turn out and forced demì pointè position. Many dancers do not meet the requirements for 90 degree demì pointè in the metatarsophalangeal joint, and therefore force this position, leading to formation of bone spurs and further decrease of motion, often accompanied by inflammation (22). Forcing the turn out often leads to a pronated foot, this being one of the frequently mentioned causes, in addition a forced demì pointè often leads to a pronated demì pointè.

Clinical picture

Patients will often present with pain, usually on the dorsal aspect of great toe. This is often accompanied with stiffness and decreased range of motion. They will often explain that pain is worsened by activity and wearing of shoes, and alleviated by rest. The pain may be worse in off-toeing face of gait and while wearing high heels. (22) (57) (73) (76) (77). Patients with this conditions, and also hallux valgus, may present with problems at the second metatarsal as well, often due to a compensation mechanisms to avoid weight-bearing of the first metatarsus (78).

Examination

Important examinations for these patients include;

- Palpation of foot/toe to locate pain, tenderness and swelling
- Range of motions tests of the toes and ankle to identify movement limitations
- Weight bearing examination, for example using scales, to see favoring of legs
- Podoscopic examination to see loading on the foot
- Gait examination to look for changed patterns and antalgic walk

For dancers it would also be appropriate to examine the posture and foot position during relevè, demì pointè and pliè (22). These positions can also be done during the podoscopi to see how the dancers hold the leg during these positions.

On examination you may find, in addition to the decreased motion, a starting bone formation of the dorsal aspect of the great toe (57), crepitus, swelling, interphalangeal hyperextension (73), hyperkeratosis of dorsal hallux, and possible metatarsalgia or paresthesia with radiation pain (76) due to compression of dorsal digital nerve of hallux (73).

Stiffness of the hallux joints may affect, and change, the patients gait pattern; thereby changing the loading pattern and influence the total foot function (76).
Gait examination will often reveal an abnormal gait pattern with lateral loading to avoid pain (22), shorter steps and possible excessive flexion or circumduction in knee and hip (73). These compensatory mechanisms of foot may lead to the patient not really having any pain by the hallux, and pain may come from other areas of foot or by other problems that have developed. These may include plantar facitis, arch strain of plantar joint pain (76). If the patient, either actively or passively, performs inversion of forefoot or adduction of foot during walking, the load will decrease on the first metatarsal or you will find few external symptoms on the hallux (76). Hence, the total amount and severity of symptoms will vary according to the amount of compensation.
If there are many compensation mechanisms and they have lasted for long periods of time many of the external symptoms can be seen on other toes more lateral on the foot.

X-rays can be taken and will often show arthritic changes in the joint as joint space narrowing, widening/and or flattening of the first metatarsal head and base of proximal phalanx (22) (57).

During the examination one may be fooled to diagnose the patient with Hallux Rigidus when this is fact is not true. The hallux may be stiff and with pain and decreased motion without being a true Hallux Rigidus. In these cases the x-ray will show no bony deformity and the stiffness will decrease once technical faults and symptoms are treated (19).

Treatment

In acute stages rest, ice, compression and elevation is recommended along with soft stretching of the foot in a non-weight bearing and pain free position (22).
Conservative treatment includes oral anti-inflammatory medications, heating procedures, stretching and range of motion exercises, mobilizations of the joint and strengthening intrinsic muscles of feet and flexors and extensors of the hallux (19) (57). Slight traction of the great toe can slow progression and alleviate symptoms by decreasing the stiffness both inside the joint and of the surrounding soft tissues (19).
Correction of posture and compensation mechanisms should also be included, and in the dancers case teaching of correct technique.

It is advisable to tell the dancer not to push their demì pointè to a full as this tends to make both pain and the complete condition worse, possibly imitating a Sesamoiditis (78). This pushing beyond limits is a common compensation for dancers experiencing problems to reach full dorsiflexion of the toe (78). Instructions on how high one can go should be included to the therapy (19). Taping the hallux to a slight plantarflexed position may help preventing this very high demì pointè, and thereby prevent the most painful positions (22).

Modification of shoe wear can be helpful, and shoes with large toe box and stiff sole might help relieve symptoms by decreasing weight to the hallux (57). Thomas M. Novella (78) in his article in the Journal of Dance Medicine and Sciences states that he has had success with use of padding in dancers with problems like Hallux Limitus, Hallux Valgus and Sesamoiditis, and states that the padding "*has helped dancers with acute injuries to perform on a given evening, and allowed those with long term injuries to continue dancing in a limited way while undergoing rehabilitation."*

If conservative treatment is not working surgery is possible.
The surgical approach is typically only for patients where the conservative treatment shows no effect, and the type of procedure depends on the severity of the injury. Research has shown that ability to return fully to dance after surgical procedures are variable, and it should therefore only be advised for patients not being able to dance as a result of their injury (22).

3.3.3 Sesamoiditis

This condition is viewed as a common dance injury by the following citations;
(19) (20) (22) (27) (51) (57) (78)

The Sesamoids are small bones that lay under the great toe (19), beneath the tendon of Flexor Hallucis Brevis, with contribution from tendons of Adductor Hallucis and Abductor Hallucis (20). There are generally two Sesamoids, called either lateral/medial (19) or tibial/fibular (22). They are quite unique as they are not connected directly to any other bone in the body (22), and they work similarly to the patella (19).

In normal walking the sesamoids take the load and pressure under the great toe and help to distribute the weight. Studies have also shown that during toe-off phase of normal gait the Sesamoids aid the movement by accentuating the force of the Flexor Hallucis Brevis (19). Forces equal to three times the body weight have been estimated to occur under the sesamoids during walking, and during a relevè the medial/tibial Sesamoid take most of the weight; hence it is more prone for injury (20). The medial/tibial Sesamoid is usually longer and larger than the lateral/fibular one (22).

Sesamoiditis is an inflammation of the Sesamoids, usually accompanied with pain during weight bearing (19).

Epidemiology

Sesamoiditis is common in athletes like runners and dancers who frequently experience excessive weight bearing loads to the first metatarsal (57). In dancers it frequently occurs when landing from jumps without the adequate pliè (22). The condition may also follow a laterally unstable ankle and several ankle sprains, as dancers then may try to avoid another sprain by compensating and shifting weight onto the sesamoids (78).
The sesamoids are prone to many types of injuries, including fractures, arthritis, tendinitis and cyst development (20).

Etiology

Causes for Sesamoiditis are as follows;

- Direct trauma caused by for example landing from a jump, this usually affecting the medial Sesamoid (19) (57)
- Prolonged working on a hard surface (19).
- Hyperpronation of foot (57)

- Technical errors, ranging from hip to toes including, forced turn out, incorrect landings from jumps, sacroiliac position or dysfunction, repetitive and/or incorrect relevè (22) (78).
- Anatomical individual differences as high arches, also known as Pes Cavus, or an excessive thick or pointy Sesamoid (22).
- Footwear without proper cushioning (57).

Clinical picture

Patient will complain of pain of plantar surface of the first metatarsal during weight bearing.

Examination

You can localize pain of the Sesamoids by passive dorsiflexion of the first metatarsophalangeal joint, while palpating the undersurface of the great toe by your opposite hand (20) (22) (57). If the pain is not elicited by this maneuver you can ask for an active relevè, and see if the pain if provoked by this weight bearing action. Pain is usually at the medial Sesamoid, and there may be swelling present (22).

Examination of gait is important and may often show you why the problems has evolved, or you can find compensation mechanisms. Also an examination of hip, knee and feet will be necessary to see if there are any biomechanical issues that might cause the overload of the Sesamoids. This will include especially tightness in hip joint, sacroiliac dysfunction, and increased pronation position in feet (22).

A frequent compensation mechanisms for dancers is "*sickling*" of the foot, meaning a lateral weight transfer on the foot (19) (22) (57) . As described regarding Hallux Valgus and Rigidus this compensation is not acceptable, neither technically nor esthetically, and will most likely lead to further injury.

For excluding fractures one can use radiographic means, and if stress fractures are present a bone scan or MRI can be done for early detection, as they don`t usually show until after some time (20) (22).

Treatment

Treatment must be aimed not only at minimizing the pain, but also to avoiding further injury. The dancers with Sesamoiditis tend to compensate their painful Sesamoids by supinating, or "*sickling*" their foot and this may lead to both ankle strains and fractures (20), and needs to be addressed.

The two main goals of treatment is to decrease weight bearing on the sesamoids, and also decrease flexion of the metatarsophalangeal joint during walking; as this puts a lot of stress on the Sesamoids. In addition prevention of contractures of Flexor Hallucis Longus, and Flexor Hallucis Brevis should be included (22).

In the acute stage avoiding excessive load should be highly emphasized, this meaning no jumps or running (57), and for the dancer no forced turn out or working on demì pointè (22). Rest and refraining from exercise for 2-3 weeks is recommended (57).

Shoe modifications can be added for weight relief, and the use of pads are quite common. Norris (20) describes a method of shoe modification he has been successful with to achieve a decrease in the weigh bearing on the sesamoids; he is either using a soft pad around the whole midfoot (with no padding on the painful area), or he uses rigid shoes where he makes a special "hole" beneath the great toe in which he fills soft foam. By these means he expresses that you will minimize both the weight n the sesamoids and also the flexion of the metatarsal during gait. This will again limit contractures of Flexor Hallucis Brevis.
Bracilovic (22) on the other hand recommends soft pads, that she calls "dancers pad", to be placed under the great toe. She also states that taping the great toe to a slight plantarflexed position can be helpful, by reducing the dorsiflexion and thereby the weight on Sesamoids.

In addition to the decreasing of weight on the great toe, education of the patient is crucial. There should be instructions in the importance of avoiding forced turn out and also proper biomechanics of hip, knee, ankle and foot (22).

According to Norris (20) treatment should also include modalities as ultrasound, deep friction massage, ice message and electrical stimulation. Stretching of Flexor Hallucis Longus and Brevis should be included (22), and also general strengthening of the intrinsic muscles of the feet (57).

Dancers should be made aware that the rehabilitation process may take time, especially if there is a stress fracture of one of the Sesamoids (20). The progression to normal dance routines should be as follows; demì pointè exercises on both feet, then on one foot, later jumps on both feet and eventually jumps on one foot, like jetè or assemblè (22).

Surgical procedures are possible but they should be the absolute last resort, as this may prevent the dancer from returning to dance (22). The biomechanical alignment may be changed and this will affect the performance ability (57).

3.3.4 Dancer`s Fracture

This condition is viewed as a common dance injury by the following citations;

(22) (23) (51) (57)

This fracture is uncommon in general population, but with a higher prevalence in dancers then the rest of the population.

Dancer`s Fracture is an acute fracture of the fifth metatarsal distal shaft (22), most commonly resulting from excessive inversion with plantarflexion of the foot (79).

Dancers are susceptible to many different types of fractures in the fifth metatarsal, this being the most common, and they may be difficult to differentiate when acute. All the acute fractures have the same symptoms of tenderness, swelling and ecchymoses of the base of the fifth metatarsal. Only radiographic examination can tell the true anatomical location of the fracture (23). In general stress fractures in the foot are common in ballet dancers, most likely due to the high demands of the en pointè position and jumping. Female dancers are also seen to suffer more from fractures, possibly because the men are protected from these injuries as they don't rise to full en pointè (7).

Delmas J. Bolin (7) states in his review of foot fractures in dancers that general causes of fractures in dancers are considered to be disordered eating, menstrual irregularities, Morton's toe, a cavus foot and technical faults. When considering technical faults he especially mentions sickling and a weight back situation, where the weight back situation will give the dancer an incorrect rising to en pointè position and increasing the load on the metatarsals (19).

In medical terms Dancer`s Fracture is called Pseudo-Jones Fracture, but due to the prevalent occurrence in dancer`s it has been given its name (79). A true Jones fracture is a transverse fracture at the proximal diaphysis of the fifth phalanx (80), but the Pseudo-Jones, or Dancers Fracture, is an avulsion fracture by the Peroneus Brevis tendon at the very end of the fifth phalanx (79).

Epidemiology

This is the most common acute fracture in ballet dancers (22), and avulsion fractures are the most common fractures of the proximal fifth metatarsal (23).

Etiology

Dancer`s Fracture can result from a direct trauma to the lateral foot (80), but more commonly it is due to indirect mechanisms (22).

The fracture is often accompanied by an ankle strain (23), and for dancers it is usually due to rolling outward and falling from the demì pointè position or landing from a jump on an inverted foot (22). In the demì pointè position there is a high twisting force to the forefoot producing enormous stress that can contribute to a fracture itself (22) (80). Landing on an inverted (and plantarflexed) foot is also common, especially in modern techniques, to make the landing seem more effortless and esthetic, thus giving the fifth metatarsal a great direct blow.

General ankle instability, history of ankle problems and peroneal weakness can also predispose dancers for this type of injury (22).

Clinical Picture

The dancer will usually describe falling from either demì pointè or full pointè position, landing on the lateral side of foot. There will be immediate pain, swelling and difficulty ambulating. If this is not the case and incorrect landing from a jump, or just the fact that it occurred during landing, might be stated (22). Limp walk is often seen and possibly an antalgic position of the whole body in the gait cycle can be found (80). The patient will be able to have weight on the injured foot, but this is usually very painful (23). The pain and other symptoms are to that extent that dancers tend to seek medical attention within the next 24 hours (22).

Examination

Palpation and X-rays are essential for getting the diagnosis correctly (79). The big problem with patient with these types of symptoms is to determine what kind of fracture has occurred and where it is located, in which x-rays are needed (23). Especially differentiation from Jones fracture is essential.

On palpation you will find bony point tenderness, swelling and pain on the lateral parts of foot. Symptoms occur especially along the fifth metatarsal, but they may be more generalized to the whole forefoot area. Also a gait examination can be helpful. Patient will be able to walk with weight on the effected foot (22).

Treatment

Conservative treatment is recommended for most cases, and surgery is preferably avoided with this diagnosis (22) (80). Treatment is usually initiated by protection, rest, ice, compression and elevation (22). Decreased weight bearing and cast can be advisable for 2-6 weeks, but this is associated with muscle dystrophy and if used it should be as short as possible (80). These means are usually prescribed according the displacement of the fracture. If the fracture has no displacement of minimal displacement the wearing of a hard sole shoe or removable walker boot is recommended with progression to full weight bearing in 3-4 weeks. For these patient immobilization is not appropriate, especially not dancers, and range of motion exercises should be encouraged. With moderate displacement (3-5mm) a short leg walker is recommended with weight bearing for 6-8 weeks. Larger displacements may be indication for surgery, but this is rare (22).

More specifically; therapeutic procedure that should be included are initially non-weight bearing exercises as swimming or cycling, limitations to active range of motion is appropriate in this time. later progressing to weight bearing exercises with improvement of range of motion is suitable combined with strengthening of ankle, stability exercises and proprioceptive stimulation (22).

Prognosis of Dancer`s Fracture is usually excellent, with the dancer returning to dance within a moderate amount of time (23). O`Malley et al. in 1996 (81) found that dancers with displaced fractures took longer to return to performance, with an average of 23 weeks, however they did not find a correlation between amount of displacement and final outcome, including residual pain and returning to performance.

3.3.5 Lateral Ankle Sprain

This condition is viewed as a common dance injury by the following citations;
(12) (19) (20) (22) (23) (26) (27) (40) (46) (48) (51) (82) (83) (84)

Sprains differentiate from strains by involving ligaments, and not muscles and tendons. A sprain is a tear of one or more of the ligaments stabilizing the ankle, and according to some authors the condition is better termed *ankle sprain syndrome*, due to its complexity as it usually involves several structures around the ankle (84).

A dancer standing in a full en pointè position is statically stabilized by the Calcaneus being locked to the Tibia. When descending from this position to a demì pointè the ankle loses this static help and is stabilized dynamically by mainly three ligaments; anterior Talofibular ligament, Calcaneofibular ligament and posterior Talofibular ligament. The main keeper of the demì pointè is the anterior Talofibular ligament in cooperation with peroneal muscles (22). In a review article published in 2008 (84) the authors state that the peroneal muscles are the first muscles to contract during an inversion force to the ankle, trying to prevent the ankle sprain. They also found that in an unstable ankle the function of peroneal muscles may prevent re-injury to the ligaments as they work as stabilizers of the joint. Further in the research they state that in dancers there tends to be an unstable position of the ankle reoccurring in their training, often causing the peroneals to be overworked trying to compensate for this instability caused especially by the en pointè position. Concluding their article by addressing a clear link between ankle sprains and peroneal muscles being overworked, and possibly inflamed. This review of literature clearly shows how ankle sprains are more complex for the dancers then just a simple tearing of ligament, and how treatment needs to consider peroneal muscles and en pointè positions when dealing with sprains in dancers.

Epidemiology

Lateral ankle strains, from inversion force, are found to be more common then medial strains, from eversion force (12) (84). According to Bracilovic (22) and Hamilton et.al (12) lateral ankle strain is the most common ankle injury in dancers, and Howse (20) even say it`s the most common injury of all to the dancer. But dance is not the only sports where this has a high prevalence; some authors state that this is the most common lower extremity injury occurring in all sports (83) and that the lateral ligaments of ankle are the most injured

structures in the body (84). It has been estimated that there are 23.000-27.000 ankle sprains in the U.S every day, and stated that females are at higher risk, and that the reoccurrence rate is very high (83) (84).

Of the three ligaments involved the anterior Talofibular ligaments is the weakest and the most frequently injured (22). It is the ligament firstly involved due to its placement and strength, and the two others follow as the severity of the strain increases (65).

Etiology

Lateral ankle sprains are due to an excessive inversion mechanism of the foot (12) (19) (84) (83), and most often it also includes components of rotation and plantarflexion (12) (19) (65) (84) . More detailed one can often find inversion and internal rotation of the rear foot coupled with external rotation of the lower leg. If the anterior Talofibular ligament is severely strained or even ruptured the internal rotation on the rear foot is highly increased, thus increasing highly the stress on the remaining ligaments (83).

Causes of lateral ankle sprains include;

- Previous history of ankle sprains (19) (22) (84)
- Fatigue (22)
- Poor landing technique from jumps, or faulty landings due to other reasons bad floor construction or footwear (12) (19) (22) (84)
- Forced turn out without muscular control (19)
- Functional predispositions as poor ankle stability and coordination, weakness of peroneal muscles and intrinsic feet muscles, general postural insufficiency, including weakness chains from unstable pelvis, lordosis etc or poor proprioception (19) (22) (83)
- Anatomical predispositions include increased Tibial Varum (Genu Varum) and increased Talar tilt (83).

Clinical picture

The dancer will typically state falling from a plantarflexed position or experiencing an improper landing from a jump (12) (22) (84). There are typically complaints of difficulty and pain during walking, and when injured many hear a click or popping sound. There will

usually be tenderness, swelling and intense pain of the lateral side on ankle, usually right after injury occurred (12) (83).

Examination:

A full examination of the foot and ankle should be done, but right after injury this may often be difficult due to intense pain, and swelling of the area (12) (22). For the same reasons a complete picture of the degree of injury is usually difficult to assess at first.

When examination is possible there needs to be palpation of the ligaments, and also bony structures and muscles, including all three main ankle ligaments, malleolus, fifth metatarsal and peroneal muscles and its tendons (83). You might find tenderness on the fibular insertion of the anterior Talofibular ligament, and if the injury is more sever also by the calcaneal insertion of the Calcaneofibular ligament (22). Fractures that needs to be excluded are especially Dancer`s Fracture and fracture of the lateral malleolus (19).

There also needs to be done an assessment to see if there is a complete tear of any of the ligaments (19). The anterior drawer test is stated to be an important tool for assessment and it puts stress on the anterior Talofibular ligament (12) (22) (83), to see the ligaments integrity. This is done by stabilizing leg above ankle with one hand, and catching heel with the other hand. The leg is relaxed to a natural plantarflexion, and you pull the heel towards you. A positive test is when you find a 3-5mm larger laxity of the affected side compared to healthy side.

The talar tilt test (22) (27) will show you the integrity of both anterior Talofibular ligaments and Calcaneofibular ligament. This test is also called inversion test, or varus stress test, and involves forced inversion of the foot comparing the two sides. Generally a greater than 23 degree angulation, or more then 10 degrees of difference between sides, have been associated with complete tears of both anterior Talofibular ligament and Calcaneofibular ligament (22).

Radiograph imaging should be included if you locate any signs for fractures; including weigh bearing pain by fifth metatarsal or pain at medial or lateral malleoli, navicular bone, tibia or fibula. X-rays will also show any talus tilt or rotation (12) (22) (83).

According to clinical finings the ankle sprain is classified into three groups (27) (65) (22).

1. Grade involves mild pain and swelling, some discoloration after 12-24 hours and relatively mild functional loss and laxity (65). This typically reflects a stretched or

only partially torn anterior Talofibular ligament, and intact Calcaneofibular ligament with no associated mechanical instability (22).

2. Grade involves moderate pain, swelling and discoloration, and the dancer may need some immobilization through a walking boot or crutches. There has now been an increase in the joint laxity (65). This reflects a complete tear of the anterior Talofibular ligament with some tearing of the Calcaneofibular ligament with the associated instability (22).

3. Grade involves severe pain and dramatic swelling and discoloration. Immobilization is necessary as weight bearing is not tolerated (65). This reflects a complete tear of anterior Talofibular ligament and Calcaneofibular ligament, with additional damage to posterior Talofibular ligament (22). In these cases subluxations and dislocations may occur (65).

Treatment

In the acute phase rest, ice, compression and elevation (RICE) should be applied (12) (22), and until the dancer has been diagnosed fracture free one should avoid weight bearing (19). Depending on the grade of the sprain the patient will need some kind of immobilization (27); grade 1 and 2 may need soft braces, and grade 3 heavier brace with reduction to softer after 2 weeks. Crutches may be used according to the patient's own tolerance to weight bearing (22). In this first phase swelling can be reduced by doing simple contract relax exercise of the lower extremity or ankle while it being elevated, and night time elevation of the leg will be beneficial. It can also be helpful during this stage to add different therapeutic means as ultrasound or interferential therapy (19).

Later the therapy should be aimed at strengthening and balance exercises for the dancer to return to dance activities (22) (27). Exercises should be started as soon as the symptoms allow it (65), and they should be done in full range of motion, and include all peroneal muscles. To start with the exercise called "*ABC`s*" can be used to improve the range of motion (65). This is exercises involving movements of the ankle, and you ask the patient to imaging holding a pen with the toes and writing the whole alphabet. Further one can prescribe non-weight bearing exercise for ankle muscles, and these should be in both neutral and plantarflexed position to include all the muscles (19).

Later there should be progression to partial weight bearing exercise and full weight-bearing exercises. This should include proprioception and balance training and continuance of strengthening (19) (22) (84). Examples of this can be starting to balance on a balance board while holding the barrè, and continuing to let go of barrè and eventually progress to standing on one leg. The balance board is stated to be the most effective way to rehabilitate after an ankle strain, according Howse (19). When evaluating if the dancers is ready to return to dance training a functional test, as one leg lateral hopping, can be useful (84). When dancers return to dance training a progressive return is advised, starting with foot on floor exercises and gradually progressing to demì pointè and then full en pointè (12).

Prognosis of lateral ankle strain is usually conserved as good, and dancers with grade 1 and 2 should be able to return to dance within 1-2 weeks. Dancer after a grade 3 sprain will need protection of the ankle up to 6 months during their training (22). Hamilton et al. (12) states that dancers with two torn ligaments usually require surgery to be able to have a successful recovery, and they state that the Brostrom procedure is recommended.
Braces can be used in all the different grades during dance training, but should be avoided if possible (83). Sprains have a tendency to lead to chronic ankle instability, and early return to dance must be weighed against the possibility of long term complications (84) if another injury should occur.

A frequent complication when dealing with lateral ankles strain is contracture of calf muscles and Achilles tendon. This will cause problems as rolling in during pliè, and it should be addressed and treated (19). As well as previously mentioned inflammation of peroneal muscles due to overworking trying to compensate for instability (84).

Solomon et al (20) has written the following plan for rehabilitation to be suitable:

- *Day 1: Apply ice with elevation and compression; no weight bearing; air cast or gel cast.*
- *Day 2: Do active exercises for ankle and foot 2-3 times a day; ice after each period; conditioning exercises for entire body, and walking when necessary with air cast.*
- *Day 3: Massage elevated lower leg, stroking upward toward the heart; swimming and pool exercises for ankle 2-3 times a day; walking with air cast.*
- *Day 4: Stretch to normal range of motion; increase resistance exercises; use balance board; continue with use of ice after exercise.*

- *Day 5: warm up foot and ankle; contrast bath 20 min; barrè work slowly with foot in tape; strength and flexibility exercises, then ice.*
- *Day 6: continue with body conditioning exercises; resistance exercises for ankle; full barrè, all speeds; walk in pointè shoes, but no work on pointè.*
- *Day 7-10: Begin small jumps and turns; resisted balance positions; rehearsal and slow pointè work.*

3.3.6 Achilles Tendonitis

This condition is viewed as a common dance injury by the following citations;
(9) (19) (20) (22) (23) (27) (46) (48) (51) (57)

Before starting this it is appropriate to state that there is a difference in Achilles tendinitis and Achilles Tendinosis. The two names are often confused, but describe two different processes in the Achilles. Tendonitis is an inflammatory process, and Tendinosis is a degenerative change in the Achilles. Tendinosis can occur without the inflammatory aspects of tendonitis, but often one can see that the two are present together (22).

The Achilles tendon is the conjoined tendon for the calf muscles (20), it is the longest and strongest tendon in the body and it connects the Triceps Surae to the heel (22) (85). The tendon is attached to a facet in the Calcaneus, and separated from the bone by a bursa (20).

The Achilles tendon does not have a sheath (19) (20), but it is covered by fascia. So the inflammatory process in either in this fascia structure or, very rarely, the tendon itself (64). The blood supply to the tendon is limited, possibly contributing to injury susceptibility (64) (85).

The Triceps Surae consists of the Gastrocnemius and the Soleus. Even though having similar functions they differ to some extent. The Gastrocnemius flexes both the knee and the ankle in an open kinematic chain, and the Soleus only plantarflexes the ankle. Gastrocnemius is used mostly for jumping, and the Soleus has a more static hold function (20). During relevè, demì pointè and full en pointè position the two work together to perform the plantarflexion (22). The tendon can sustain more than 1000 pound forces (22), and due to the physics involved the pull on the Achilles is less in full pointè or high relevè, then during low demì pointè or relevè (20).

Epidemiology

Achilles tendon is frequently victim of overuse injuries, especially in sports with frequent jumping. The tendon is especially susceptible to inflammation in dancers, gymnasts, runners and cyclists (22).

Etiology

There are many known factors the contribute to the development of Achilles Tendonitis;

- Overuse of calf muscles, often seen during periods of excessive training due to performance preparations or intensive summer courses (19) (22).
- Improper warm up and progression (85).
- Shortness of calf muscles, which is common in dancers due to the constant plantarflexion (20) (22).
- Excessive pronation or supination position of the foot (20).
- Weakness of feet in general, including intrinsic feet muscles, Gastrocnemius, Quadriceps, Hamstrings or Gluteals (19).
- A low relevè, as this gives more stress on the tendon (20).
- Hyperextension of knees, this putting extra strain on the Gastrocnemius (19)
- Have weight bearing to far back on the foot (19).
- A sudden start of exercising again after absence from dancing (22).
- Shoe wear and floor without shock absorption (22).
- Anatomical variations of the Achilles, with the smaller and thinner ones being more susceptible to injury (20).
- Anatomical restrictions to the pointè of the foot, like an Os Trigonum or an enlarged tubercle of talus, can also participate (19).

Even thought this list is quite long, it all seems to narrow down to overuse of the calf muscles, either due to excessive training, faulty positions of feet, or weakness.

Clinical picture

The typical presentation is a patient with pain 5-10cm above the insertion to the heel (22) (85). Usually the pain has a gradually progression, and it is often with insidious onset. Dancers don`t usually seek medical help until the pain has lasted for a long time, and has worsened to the extent that it is present also during gait and relaxation, and is interfering with performance (64). The pain if often worsened by jumping, and the patient might state that he has frequently started to train more or harder then before (22). There might be some swelling and redness (65).

Examination

Palpation should be done and may reveal swelling, pain and tenderness. There might be possibilities to palpate a fusiform swelling in the painful area, but one should not find any other defect that might be symptoms of a rupture. There might be pain during resisted plantarflexion and passive dorsiflexion. During movement of ankle crepitus can be felt in the Achilles (22).

Achilles tendonitis can be found in different degrees of severity ranging from mild irritation to small tears and fusiform swelling (20).

Differential consideration should include excluding injuries as retrocalcaneal bursitis, calcaneal stress fracture, tibial stress fracture, posterior tibial tendonitis, tarsal tunnel syndrome, ossicle formation of talus (Os Trigonum) (64). Imaging methods are usually not necessary, but can be used in cases where other injuries need to be excluded (22).

Treatment

Acute treatment involves reduction of pain, edema and inflammation. This will include RICE principle (rest, ice, compression, elevation) and physical means as ultrasound, interferential therapy and contrast bath. Exercises can be performed in mildly affected patients to keep range of motion, but only within pain limits. Dancers with mild inflammation and pain who feel they can continue some training can place a heel pad inside shoes to limit stress on the Achilles during pliè, or wear character shoes with a slight heel. (19) (20) (22) (64) (65) .
According to both Solomon et al. (20) and Howse (19), injection of steroids is highly improper method of treatment as if may weaken the tendon and predispose it to a rupture.

When the acute phase has passed and pain has decreased focus should be hold to restoring range of motion, strength and length of muscles. Exercises should be done, especially eccentric exercises, to strengthen Triceps Surae. Gradually one should increase difficulty of exercises and amount of strength required. Strengthening in swimming pool and practicing jumps and landing there can be very helpful (19) (22).
In the longer run technical error should be addressed, and finding the source of the overuse. According to Howse (19), if the therapy as stated above has no effect it is usually due to an underlying serious technical fault that limits the rehabilitation process.

3.3.7 Shin Splints

This condition is viewed as a common dance injury by the following citations;
(9) (22) (27) (46) (48) (59) - *In addition this was the main complaint of the students when I visited the dance conservatory in Bergen, Norway in 2011.*

Shin splint is a broad term describing pain on the anterior, medial and/or lateral parts of the calf/shin. It is also frequently called Medial Tibia Stress Syndrome, Tibial Stress Syndrome and Periostitis (22) (29) (70).

Epidemiology

Common in athletes who train on hard surfaces and that suddenly increase intensity or frequency of training. Especially found in runners, ballet dancers and gymnasts and often together with other overuse injuries. It is a typical overuse injury with increasing intensity of symptoms parallel with increasing intensity of training. Found twice as often in woman than in men. (22) (29) (59) (70).

Etiology

The etiology of shin splints is quite unclear, but there exists several theories;

- Inflammation of the periosteal sheath of the tibia with associated irritation pain from surrounding tissues. The inflammation may be resultant of forceful activities as running and jumping, or forced dorsiflexion with increased weight bearing (22) (70)
- "*Doing too much too soon*", either by overestimation of own abilities or returning to training after a longer break (29) (70)
- Traction injury from medial Soleus muscle (70)
- Bone stress reaction (70)

Risk factors for development of shin splints also include;
Foot pronation, training errors, hard surfaces, improper shoe wear, tightness of Gastrocnemius and Soleus propelling body forward putting stress on Tibialis Anterior, muscle imbalance between dorsiflexors and plantarflexors with decreased dorsiflexion, leg length discrepancy, tibial torsion, excessive femoral anteversion and inadequate warm up (29) (59) (70).

Clinical picture

The patient will typically complain of pain on the anterior or medial aspect of Tibia that is worsened during class and while running or jumping (22). The pain is often described as dull and aching (70), and it is usually bilateral (59).

In milder cases the pain may disappear after training, but in more severe cases the pain continues after ceased activity, and may even be present during normal walking, activities of daily living and at rest (59) (70).

Examination

Firstly, general observation of the patient is important. Foot position should be seen, and look especially for Pes Planus, hindfoot valgus and foot pronation (70). It is also important to examine the gait and look for any imbalances or asymmetries in walking, but also in pliè and relevè (22).

Palpations will normally reveal tenderness along the posteromedial border of Tibia, especially over the middle and lower parts (22) (70), and swelling may be present in the area (59). With increasing severity the tenderness may be felt higher (70), but in children it will be more common to palpate pain on the proximal parts even with lower severity (22).

There should be differentiation from fractures of the Tibia, and this can usually be done by the pain findings during palpation. A fracture will have more localized pain over the bony area that is injured, and if this is found imaging methods should be prescribed (59).

Usually resisted plantarflexion, toe flexion or doing a relevè will increase symptoms, and you may find pain-inhibitory weakness in these examinations (59). Pain in stretching of the Soleus may also be evident (70).

Shoes, both dance shoes and street shoes, can also be examined to look for signs of increased foot pronation (22).

Imaging methods will show up normal during shin splints, but can be helpful in diagnostics as to differentiate from other injuries. Injuries of special importance here will be Chronic Exertional Anterior Compartment Syndrome, Tibial fractures, popliteal artery entrapment and fascial hernia (70).

Treatment

In acute stages rest, ice, compression and elevation is the mainstay of treatment (22). Decreasing specific exercises that produce pain, as jumping etc, can in the mild cases be enough, but when this is not helpful absolute rest is appropriate until the dancers is symptom free (22) (70). In general one should avoid repetitive lower extremity stress for 1-2 weeks (59), and with absolute rest the symptoms may decrease within 3 days to 3 weeks (70). If weight bearing is painful crutches can be indicated until symptoms resolve (59).

In the acute phase non-steroidal anti-inflammatory drugs may help to treat pain and inflammation (22)(59)(70). In addition physical means as ultrasound, whirlpool and ionothoporesis may help in this early stage (59).

Long term treatment should focus on correction of training errors, or biomechanical faults in feet, to remove it as a possible cause of injury (29) (70) . In addition strengthening and flexibility programs should be made to improve imbalances (29), and prevent reoccurrence (59).

As there is some discussion around the etiology of shin splints there is also some differences in what muscles are recommended to being stretched and strengthened. Some state that the primary muscles involved are Flexor Digitorum Longus and Soleus (59), and some state that stretching Triceps Surae, Tibialis Anterior and plantar muscles and strengthening intrinsic feet muscles is important (22). But there is a general agreement that range, flexibility, strength and balance in ankle and foot is very important.

3.3.8Ankle Impingements

This condition is viewed as a common dance injury by the following citations;

(3) (10) (12) (22) (46) (48) (51) (57) (86)

Ankle impingement is a painful condition o f the ankle due to "squeezing" of soft tissues, usually due to anatomical changes in the ankle joint (87), or due to excessive movements and overload of the ankle structures. When plantarflexing and/or dorsiflexing the foot the Talus changes its position in the mortise, and may come in contact with the Tibia. Where these two bones contact will determine the area of pain, and also the name of the impingement; anterior or posterior (46) (57). To pointè the foot fully the dorsal side of the foot should be parallel to the long axis of the leg, and this extreme plantarflexion found in dance often causes problems in the posterior ankle. In the same manner the frequent pliè and landing from jumps causes an excessive and repeated dorsiflexion, putting stress on the anterior ankle (12).

Further in this text I will discuss the two syndromes, anterior and posterior, separately.

Anterior impingement:

Epidemiology

Anterior impingement is a relatively common cause of anterior ankle pain and occurs especially in athletes who perform repetitive dorsiflexion (12) (57) (87). It is frequently seen in ballet dancers (57) (88) due to the repetitive use of pliè (22). Landing from jumps involves forced dorsiflexion, and as males tend to have more jumps in ballet males are often seen to be affected more often than females (46). Other athletes often seen with this type of problem includes football players and soft ball catchers (57) (87) (88).

Etiology

When the ankle is excessively dorsiflexed, like during a pliè, the Tibia may come in direct contact with the Talus. This repetitive abnormal trauma may cause development of bone spurs that compress the surrounding structures and cause pain. This situation with bone spurs development will cause the impingement to occur at an earlier stage of the pliè, hence also inducing pain earlier and limiting the range of motion (22) (57) (87) (88). This etiological explanation is common throughout newer literature, and all authors seem to agree that the trauma due to repetitive excessive dorsiflexion is the sole reason for this situation to occur. Another common finding is that repetitive ankle sprains may be a predisposing factor (12) (22) (88).

Clinical picture

The patient usually presents with a dull, aching and chronic pain at the anterior aspect of ankle joint. The pain is usually worsened by pliè (hence a weight bearing dorsiflexion) and the dancers may also complain that the depth of her pliè has decreased (12). She/he may feel that something "is in the way", and limiting their ability to fully pliè (22) (46). There might be swelling, tenderness and an inflammatory response around the ankle with decreased range of motion accompanied with pain at the end of range (57). Clicking and crepitus may be present (22). In severe cases of inflammation of anterior ankle joint the pain may even be elicited by plantarflexion, a passive stretch of anterior structures (12).

Examination

Examinations should include a full postural and functional check. Observation should be used to find changed movement patterns of ankle, and in the dancer pliè needs to be included to the examination. By palpation one may be able to locate the area of pain and also detect swelling around the ankle. With a slight plantarflexion one can find osteophytic changes of the joint, on the anterior Talus or Tibia. Examination of range of motion usually shows limited movements with pain at the end ranges, typically dorsiflexion but this may also be true for plantarflexion. Imaging with plain radiography can show development of bone spurs and may be helpful to conclude the diagnosis. Not all impingements have spur development, but the imaging can also be used to exclude fractures and arthritis. (12) (22) (88) (89) .

Treatment

Initial treatment involves rest, ice, compression and elevation, often combined with non-steroidal anti-inflammatory drugs. In addition a heel lift inside shoes can be appropriate to limit the dorsiflexion, and for the dancer the pliè should be limited (12) (22) (46) (89).

If this initial rest and limitation does not help further bracing or taping of the ankle can be helpful, with instructions to the patient of how further pushing the ankle will make the condition worse (89). In contrast to many other injuries occurring in dance stretching and strength training will not help, only aggravate the condition (46).

If conservative treatment does not help the condition due to large spur development, surgery is indicated. The surgery may remove either impinged soft tissue of bone spurs (22). After surgery rehabilitation with stretching and range of motion and proprioceptive exercises is indicated. The patient may be back to sports within 7 weeks, but jumping should be limited until after 2 months of rehabilitation (89).

Posterior impingement

Posterior ankle impingement can also be called "Dancer`s Heel" (22).

Epidemiology

Posterior impingement is rare in the general population, but an important cause of chronic pain in ballet dancers, runners and football players (87) (90). This condition has a uniquely high occurrence in dancers, especially ballerinas dancing en pointè (22) (46).

Etiology

The causes for posterior impingement are many, but in literature excessive plantarflexion or the presence of an Os Trigonum is a reoccurring finding (12) (22) (46) (87) (89) (90).
The impingement is normally due to trauma or overuse. Overuse etiology has a better prognosis, and is the common type in ballet dancers (90). Young dancers often present with symptoms after advancing their pointè work and more experienced dancers after a change in training or performance (86).

Repetitive plantarflexion of the ankle, as seen in ballet dancers during en pointè positions, gives enormous stress to the ankle joint, compressing both soft tissue and bony points of the posterior ankle (12) (89). Structures usually get entrapped between the posterior distal Tibia and the Calcaneus when the ankle is plantarflexed (90), this producing a "nutcracker phenomenon". This nutcracker again produces an inflammatory response of the capsule, over longer periods of time this can change the inflamed tissues to become fibrotic and thickened, that again worsen the entrapment (46) (86) (89).

The presence of Os Trigonum may participate in the development of posterior impingement syndrom (12) (22) (46) (89) (90). This is an accessory bone found posterior to the Talus, it is believed to be present in 2.5-14% of normal feet (12) (22) (89), usually without causing any problems. In dancers however this accessory bone will produce a nutcracker situation like mentioned previously, when they are in plantarflexed positions.

Other conditions that may be considered etiological are inflammations of Flexor Hallucis Longus or ligament laxity (22) (87).

Clinical picture

The patient will typically present with pain on postero-lateral aspects of ankle, possibly with associated tenderness and swelling and inability to point fully. Forced plantarflexion is painful and will reproduce the symptoms patient complaints of, this is frequently called plantarflexion test. (12) (22) (46) (87) (89) (90).

Examination

The only special diagnostic tool for this diagnosis is the plantarflexion test/plantarflexion sign. This test will help to identify the impingement syndrome and also differentiate it from inflammation of Achilles tendon, Peronei and Flexor Hallucis Longus. The test is produced in neutral position and supine, and the therapist produces passive forced hyper-plantarflexion of the ankle. Pain will indicate posterior impingement (12) (22) (90).
Plain radiographs can be used to identify Os Trigonum.

Treatment

Initial treatment is rest, ice, compression and elevation often combined with the use of non-steroidal anti-inflammatory drugs. Immobilization and dance limitations may be necessary to keep within pain free limits for the first weeks. This is usually the recommended strategy for the first two weeks. Further treatment should involve stretching of Achilles and Triceps Surae, strengthening of feet and calf, proprioceptive exercises, range of motion improvement and dance technique correction, especially of "sickling". Slow progression is advised, and rehabilitation with this conservative treatment is estimated to be between 6-8 weeks. (12) (22) (46) (89).

Surgical treatment is an option if conservative treatment is unsuccessful and the Os Trigonum or impinged soft tissue needs to be removed. This usually requires approximately 6 months of failed conservative treatment, and post surgery recovery may be up to 12 weeks (22) (89).

3.3.9 Flexor Hallucis Longus Tendonitis

This condition is viewed as a common dance injury by the following citations;
(12) (19) (20) (22) (26) (27) (48) (51) (57) (76)

The Flexor Hallucis Longus tendon runs behind the medial malleoli together with the tendons of Tibialis Posterior and Flexor Digitorum Longus. The Flexor Hallucis Longus can be thought of as the Achilles Tendon (20) (27) of the great toe as it does the same for the great toe as Achilles does for the ankle; complete push–off during strides and jumps (20). The condition is also called "Dancers Tendinitis" (12) (27), and in later worsening stages names as "Trigger toe" or "Hallux Saltans" may be used (22). Hamilton et al. (12) state that large strain is put on the tendon during pointing of the foot, and that dancers need strong flexor hallucis to cope with all the point work without an inflammation to occur.

Epidemiology

Flexor Hallucis Longus Tendonitis is a very common injury in ballet dancers (12) (48), and it mostly occurs in female ballerinas (12) (22). Found almost exclusively in dancers, but may also occur in other sports including frequent jumping and running (76). When a dancers complaints of problems by posteromedial ankle this is the tendon that usually is involved, rather than Tibialis Posterior Tendon (20). It is less common then Achilles Tendonitis, and mostly occurs in inexperienced dancers (27).
The condition seems to arise more often in left leg then in right, maybe due to the predominance of right turns in choreography (20).

Etiology

The most frequently stated cause of the tendonitis is anatomical. A special anatomical variation has a tendency to make the Flexor Hallucis prone to this kind of overuse injury.

Anatomically the tendon of Flexor Hallucis Longus passes through a fibro-osseous tunnel behind the malleoli. This tendon is unique among the tendons passing posterior to the medial malleoli as it passes through this special tunnel (20) (22) (27).
As it passes through the tunnel it is easily strained or stuck, especially during dorsiflexion, as in a pliè, onto full plantarflexion en pointè (22).This frequent translation may cause an irritation of the tendon resulting in inflammation, swelling and pain. A vicious circle appears;

as the tendon is strained it gets more inflamed and swollen, and as it gets more swollen and inflamed it more easily gets stuck inside the tunnel. (12) (20) (22) (27).
In addition adhesions and nodules may appear.
Nodules may cause the tendon to get stuck and make a clicking sound frequently stated by dancers (22), it may also lead to tears. This development of a nodule is often referred to as Hallux Saltans or trigger toe (27). If adhesions occur the condition may mimic arthritic disorders as Hallux Rigidus (pseudo Hallux Rigidus) (20).

Another cause may be malalignment of the foot, or faulty technique, as pronation (20)

Clinical picture

Typically the dancer complaints of clicking or locking of the hallux during translation from pliè to relevè, and it may or may not be painful initially (22). Often the occurrence of symptoms may be related to change in training regime (27).

Examination

On examination one will find tenderness and/or pain on posteromedial aspect of ankle on tendon itself. Palpation can be done by passive dorsiflexion of ankle and palpation medially and approximately 1cm anterior to Achilles tendon; typically inducing pain and crepitus. (12) (27).

There are three possibilities of pain location (12) (22) (27);

- Along the course of the tendon through the tunnel posterior to the medial malleoli. This being the most common site.
- Under the first metatarsal base where the tendon crosses the tendon of Flexor Digitorum Longus, also known as knot of Henry.
- Under first metatarsal head where the tendon passes between medial and lateral Sesamoid.

Thomassen`s sign is a special test reflective of Flexor Hallucis Longus Tendonitis (12) (22). There are some disagreements in literature on the performance of this test. Hamilton et al. (12)states that the test is performed with passive dorsiflexion of ankle and hallux simultaneously, and that pain reflects tendinitis. Others (20) say that patient should be seated on bench with flexed knee and firstly you test range of motion of the hallux in neutral position

of the ankle. Then the range is tested when the ankle is in plantarflexion. With tendonitis the passive range of motion in neutral ankle position is decreased compared to when the ankle is in plantarflexed range. Plantarflexion of the ankle releases the tension on the tendon.

Nodular thickening, trigger toe, can be seen typically as clicking, snapping or the tendon getting stuck attempting to pass through the tunnel (22). Applying pressure directly to the tendon may also give a "trigger" reaction, hallux saltans (12).
Radiographic imaging can exclude fractures of Os Trigonum, and differential considerations should especially concern posterior impingement, fractures and insertion Achilles tendonitis (27).

Treatment

Treatment is usually a combination of anti-inflammatory drugs, stretching and strengthening (19) (20) (27). Initially rest, ice, compression and elevation is recommended, possibly combined with non-steroidal anti-inflammatory drugs, to decrease the acute inflammatory stage (12) (22) (27).

Later procedures that have been indicated are;

- Application of thermotherapy as continuous ultrasound or ice massage (20).
- Electrical means to decrease pain and swelling and improve circulation, as ultrasound and interferential currents (19) (20) (22).
- Soft mobilizations (22).
- Stretching of Flexor Hallucis Longus (20) (22).
- Strengthening of Flexor Hallucis Longus (19) (20) (22).
- Strengthening intrinsic foot muscles (19).

Immobilizations or orthosis may be used to treat malalignment of the feet worsening the condition (20) (22). Steroid injection should traditionally be avoided in an office setting as the risk of putting it to the tendon is to high, hence weakening the tendon and increasing risk of rupture. Nevertheless with sonographic imaging the injections directly to the Flexor Hallucis Longus sheat is possible and this might give good results (20) (22) (27).
Ruptures require surgical intervention and recovery may take up to one year (20).
If conservative treatment is not successful surgery of the stenosing tunnel is an option (12) (22).

4. Prevention of Injuries

Prevention of dance injury has been the primary focus of the International Association of Dance Medicine and Science since they started their work in 1990 (20).

In my opinion, and also seen previously in this text, prevention of the common injuries is very important as the treatment and rehabilitation often cause a lot of problems for the dancer; including periods away from both work and training and the physical, economical and psychological aspects of this. This seems to be the overall agreement found in literature as well, and Solomon et al (20) state that prevention of injuries needs to be the primary focus as the typical dance movements as turn out, pointè work and jumping put repetitive stress on the body.

Howse`s book "*Dance Technique and Injury Prevention*" (19) list the following as important regarding prevention of dance injuries;

- Development and maintenance of good technique
- Development and maintenance of muscle strength and joint mobility
- Preservation of cardio-respiratory fitness
- Good nutrition
- Assessment of students before starting professional dance schools

When reviewing the common dance injuries in the previous chapter one can clearly see how poor technique is an important factor in the development of injury; hence important in the prevention. Although improving technique can be the first step in prevention I have chosen to look at some additional techniques that often are said to aid inn improving technique and preventing injuries. These techniques are something I hope can act as an additional prevention technique outside the dance class, as the prevention of dance technique is the main focus in the dance class. There are also however some additional training methods that state to improve technique as well.

When choosing the techniques to focus on in this thesis I decided to look at some of the most used and mentioned methods found throughout my view of literature in the dance world. In addition some techniques that to some extent correspond to the list from Howse just mentioned above. One would imagine that if there is a possibility to incorporate several of these points into the dancers training routine that injury frequencies would go down.

One would assume that with the extensive use of some types of conditioning and training that results and effects have been looked at to some extent. For me it would be interesting to see if any of these following concepts could be used to prevent injuries by limiting or removing factors causing injuries in dancers.

Pilates is a widely known "Mind-Body" technique that is used by many of the general population and also extensively in the world of dance. I find the use of this technique very interesting and would like to see if there is any scientific evidence to the effects of this type of conditioning, and if it in any way can be used to prevent injuries. Since Pilates is widely used by dancers one would assume that the effects have to some extent been researched. I myself have some experience with Pilates through my own "dance life".

In the later years mental imagery has been very popular and there have been published several books on the topic of imagery in dance. This has also been a topic when the International Association of Dance Medicine & Science has had workshops in the latest years.
I personally have limited experience with these techniques, but know that many dancers use imagery to improve technique and performance. For this reason I would like to see how these techniques might improve dancers technique and possibly decrease the amounts of injuries.

In dance there is a large use of these "mind-body" concepts for both conditioning and rehabilitation. However, in the later years there has been a large discussion in the field of dance medicine on the use of fitness exercises, or strength training, also can be very beneficial for dancers. Since I am looking at mostly "mind-body" concepts, I would also like to include "the opposite" type of training to see what researchers have found regarding this.

Before starting to look at these techniques I have first chosen to look deeper into the topic of screening and education. This topic is widely discussed in the field of dance medicine, and its effects on prevention are often stated as being very positive. By educating dancers and screening them properly one can also incorporate the two last points from Howse in the list above.

4.1. Education and Screening of Dancers

While going into the world of dance medicine and science one can at once see how education and screening of dancers is a great issue of discussion. As the research in the field of prevention and injury is quite young and undiscovered the importance of screening and education seems to be of high importance to different organizations and institutions; possibly due to the overall agreement in sports medicine that screening and knowledge prevents injury in all types of sports. In my opinion one can to some degree compensate for the lack of research in preventive areas by being "ahead of time" with screening and education of dancers.

Solomon et al. (20) divide screening into two different types; physical screening of dancers to find anatomical issues or precursors of injury , or screening through survey, mostly used to identify injury occurrence and severity for use in research. Both of these types will be discussed here.

Harkness Center for Dance Injuries (41) is the leading institution for injury prevention and treatment of dancers. They have a clear focus on prevention and their main way of doing this is through screening and education of dancers. At their center they offer free consultations for dancers with the goal of preventing injuries. I quote their website (91);

> "*The Harkness Center offers one-hour, free-of-charge injury prevention assessments for dancers. During the injury prevention assessment session each dancer is seen individually for an hour by a therapist who reviews the dancer's complaints, medical and nutrition histories and performance during a battery of tests. The screening is designed to evaluate the risk the dancer is exposed to and to discuss the dancer's concerns before an injury occurs. At the conclusion of the assessment the dancer is given an individually tailored injury prevention exercise regime with recommendations for modification of their technique, training strategies, footwear and/or dance environment. The aim of the screening is to maximize each dancer's potential for wellness. Thousands of dancers have participated in this program and have rated it 3.9 out of a perfect 4.0 for its relevance and helpfulness."*

In addition to these screenings they offer other individual programs and also workshops and courses. They have also developed screening forms that can be used by health care providers that can aid in a screening process; "*Harkness Center for Dance Injury; Preventative Screening Form* (Appendix 2). The developer of this screening- form describes, in her article

on the subject of screening, the goals and reasons for the different parts of this form (92). This form is used in physical examination of the dancers and includes dance-specific tests to show technique and also detect precursors of injury. This is physical screening with the main goal to aid dancers in their career, however, the forms themselves could of course also aid in the development of norms for research.

The offer for dancers at the Harkness center is a very good, but from my experience no other countries have this kind of follow-up of dancers outside educational institutions as college dance schools.

The International Association of Dance Medicine & Science (93) has also had their focus on screening processes, both physical and research survey types. Their publication "*Journal of Dance Medicine & Science*" had in 1997 a complete issue (volume 1, number 3) dedicated to screening of dancers. In the introduction to this issue of the journal (94) Karen Clippinger introduces some aspects of screening to aid in the research of dance medicine;

> "*Screening of dancers is necessary if we are to establish the norms for various parameters such as body alignment and relevant anatomic deviations, range of motion and muscular strength at key joints, body composition, cardio-respiratory fitness, and aspects of neuromuscular coordination. Initial research suggests that, in some areas, the normal physiological and anatomical values found in dancers are highly divergent from those seen with other athletes or other populations, and standard orthopedic or physiologic norms may hold little relevance."*

In additions to the preventive aspects of screening processes these aspects are also very important to be able to advance the base of research done in the field of dance medicine. The lack of assessment tools and norms seem to be the one point that all authors state to lack in this field, and it is usually mentioned in the research that is done that the need for this is quite large.

For early detection of injury, and other health issues, screening processes should be a part of the audition process into dance companies and dance college programs (95). In Norway I know that the higher education programs in dance have their own screening team at auditions that evaluate all the applicants. However, in Norway there is no routine for the high schools with dance programs to have this kind of health staff attending their auditions. In the same manner dance schools with elite programs of dance in Norway seldom offer any kind of

screening for their students. In my opinion if dancers have been training heavily daily for several years throughout high school the damage may already be done as they apply for college programs in dance. For a fear shoot at a career in dance, and also for best possible technical skill development, high schools and elite programs should start screening processes in my opinion. In Israel this kind of high school screening has been subsidized by the government and is integrated as a compulsory part of dance program auditions (96).

Screening has been found all over the world, and Itzhak Siev-Ner et al. (96) has nicely summarized and listed the benefits of screening processes in dance;

- To detect risk factors at an early stage to prevent injuries.
- To learn body characteristics of dancers so it can be used as a baseline for comparison when injury occurs.
- To collect data for use in research to distinguish between "normal" and deviation.

In addition they comment on the legal benefits of these screenings; how the early detection of problems can limit later legal claims, and also how it might protect dancers from demanding teachers of choreographers (96).

Similarly to the form from Harkness (Appendix 2) Solomon et al. (20) have a chapter in their book on how dancers could physically be screened and examined. They go through a basic physical examination with emphasis on how dancers normally behave and what to be aware of during the exam. In addition to this they deeply describe how the Bartenieff Fundamentals can be used to evaluate the dancers for postural faults and movement pattern errors. They state in this chapter that most injuries occur due to an overload of faulty movement patterns that the dancers have developed during their training. Their solution is to take the problems from the roots, and try to identify and remove these patterns before they cause any problems for the dancers in form of injury. Doing this would require some kind of screening process of the students and dancers.

In 1993-1994 the Boston Ballet implemented a pre and post season screening program into their company (97). The screening was done by physical therapists, which also were available to the dancers all day, all season, for therapy. The program seems in my opinion optimal, and even though the project meet some skepticism from both dancers and teachers of the company it was a great success. Their goal was to decrease the injury rate and also the costs of health

problems among their dancers. The injury rate went down, but the cost of this project is not mentioned in the article.

In a pre-professional ballet school a screening was performed to evaluate how these younger female dancers' bodies were handling the pressures of dance during the pubertal face (98). The dancers were aged 12-18 years and all attending School of American Ballet where they took 8-12 classes per week. The results of this screening highlighted the need for education of these dancers to ensure safe dancing. The authors emphasize how it is equally important to teach these young woman about safe dancing around growth spurts, how to build their bone density for the future and the dangers of amenorrhea, as stretches and strengthening exercises. This pointing to the next topic of this chapter; education of dancers.

Education is according to Solomon et al. a key element in prevention of injury (20). They state that knowledge on injury will aid in the early detection of them, and also in the ability to make modifications of routines. However, the dance teachers alone are seldom able to make these observations of all their students; making it more important for the dancers themselves to be able to detect their own weaknesses and work with them.

During my brief period lecturing at Langhaugen High school of dance I could clearly see how these dance students were in need of information regarding their own health and how they could prevent injuries occurring during their training. I was as the school to lecture about brief dance-specific anatomy, common injuries and injury prevention. A quick and anonymous questionnaire I made of the students (Appendix 3) also reveled how they themselves felt that there was a need for information on the injuries and especially how and why they do occur. I was also very surprised at how little knowledge these students had regarding their own anatomy and health in general. The questionnaire was intentionally made for my own learning and for me and my lectures to be evaluated by the students; however it also told me a lot about what the student felt they had gained and what they would like to have learned more about. It was clear from the lessons and this questionnaire that this kind of lectures would be very helpful for these students. 42 students answered these questions and all of them stated that regular lectures on these topics would be helpful and beneficial for their everyday life with dance.

After my lectures had ended (3 times 1,5 hour lectures with each class) and the students returned to daily trainings the dance teachers at the school gave me several comments on how several of the students has changed for the better in the way they worked with technique

during the classes. However, as we did no official study or pre and post lecture evaluations of the students we have no insurance the there really was any changes, but this experience does however make me feel that there are several possibilities to make changes in the injury development in these students. The above cited research also indicates this.

Educating dancers can also be effective in preventing eating disorders. Doyle Lucas et al. (99) developed a DVD based educational intervention that they evaluated the effect of during a summer dance camp with several attending dance companies. Their results show that the intervention significantly improved the dancers knowledge in target areas of the program, including; nutrition, perceived severity of female athlete triad and self-efficacy for adopting healthier dietary habits. The study was done on adolescent pre-professional ballet dancers, and a DVD based program like this is stated by the authors of being a low cost en effective alternative in educating dancers and preventing health issues. A six week check up of the students showed however a slightly decrease of scores compared to the post-program scores. But this would possibly happen after any kind of intensive program, showing the importance of regular educating possibilities of young dancers like this.

Couillandre et al. (100) also state in their article on effects of kinesiological awareness that;

> "*Knowledge of the discipline of kinesiology, including biomechanics and anatomy of the body, may help dancers, dance teachers, and health professionals increase their ability to analyze dance movements and detect those that may cause injury. Due to the inherent joint mobility found in dancers, even minimal improvements in their biomechanics can be of value*"

4.2. Specific Techniques

In this chapter I will review techniques, or concepts, that are widely used in the dance world for conditioning purposes or to improve technique. Hopefully these techniques that dancers already often use can be a part of injury prevention by removing the factors often causing injuries.

In the recent years it has been discussed if dancers are physically prepared for the demands that are placed on them during dance training (101) (102) (103). Sir Peter Wright, the artistic director of Birmingham Royal Ballet has been stated as being the first one to introduce the term "*performing athlete*" (102) when dealing with dancers; recognizing how dancers are under the same physical stresses as other athletes, hence also needing the same amount of fitness. In the recent years there has been done a lot of research comparing dancers to other athletes, and especially the level of fitness (103). It has been suggested that the found low levels of fitness in dance may be related to the high levels of injury incidence seen in dancers, and that it might interfere with skill development and ability to reach maximal potential (101).

Rafferty (103) states that researchers are questioning if the dance class is sufficient training for the dancers of today, when looking at the physically demanding choreography and present life of dancers. She points to Chmelar and Fitt`s "Dance *Training Pyramid*" and how researches today question if the traditional dance class is able to incorporate all the aspects of the pyramid into the class.

This pyramid contains three aspects;

- *Technique class*; skill development, providing general strength, endurance, flexibility, alignment, coordination, and neural integration.
- *Somatics*; body therapies, guided imagery, neural patterning, proprioception and constructive rest.
- *Conditioning*: concerning elements of physical fitness and personal development.

Traditionally the dance class has been believed to provide all necessary training for dancers (104), however Rafferty (103) states that researchers have found that the traditional class gives only limited stimuli for positive fitness adaptations. Research she has reviewed recommends either small changes of the structure of the dance class to be able to incorporate all aspects of the pyramid, or to add supplementary sessions. Koutedakis et al (102) have also found that strength and fitness supplementary training can be beneficial and increase muscular

strength without interfering with esthetics and performance. However, they state that any change in the traditional class training must be approaches with caution so that the esthetic parts of dance is keep at the highest possible level.

Krasnow (105) states that today it is becoming more common for dancers to engage in other forms of training to supplement the dance class. She states that the typical types of training methods can be categorized as either conditioning methods; increasing strength, flexibility or cardiovascular fitness, or somatic methods or "body therapies"; working with movement patterns and neuromuscular re-patterning.

4.2.1 Mental Imagery Techniques

As mentioned in the introduction to this chapter dancers use both somatic- and conditioning concepts for improving skills and limiting injury, and imagery is a part of the somatic branch (105) .

Mental imagery has been used for many years by many different professions, including physical therapy for the elderly, sports psychology and treatment of neurological disorders (100). Imagery is considered a psychological skill, and is often associated with high levels of performance (106). It can be defined as a psychological activity that evokes physical characteristics of an object or an event, without it being the same as mental practice; practicing movement or sequence of movements in your head (107). Often it involves seeing oneself or parts of oneself in action. Krasnow et al (107) reviews the older studies and literature on imagery practices and cites Overby (1990) and his categories of different types of images;

- *Visual imagery is nonverbal memory representation of visually-comprehended concrete objects or events in which such representations are actively generated and manipulated by the individual*
- *Kinesthetic imagery is a nonverbal memory representation of kinesthetically-comprehended movements in which such representation is actively generated and manipulated by the individual*
- *Direct imagery is a nonverbal representation of an actual movement.*
- *Indirect imagery is a metaphorical image indirectly related to a specific movement. This form, sometimes called metaphorical imagery, is the representation of the desired movement with a figure or likenes.*

- *The terms internal and external imagery refer to the perspective. While internal imagery involves seeing and feeling from within the process, external imagery involves imagining as if viewing a vide.*
- *Global imagery, which involves totality images, creates an overall state or feeling sense.*
- *Anatomical imagery refers to images that specify muscle or joint action, and skeletal structure.*

Research done on the development of imagery in dancers show that most dancers do use images to improve skill and technique, and that their imagery is mostly developed naturally in the course of their training (108). In research few dancers stated to have been formally though this skill, and many dancers also stated that imagery was an internal experience that could not be thought, showing that they lack awareness that this is a skill (106).

Nordin and Cumming have done research on both professional dancers and a mixed sample of dancers. They found that dancers tend to use imagery more as their levels increased and also that full-time dance students had a more structured instruction in how to use imagery compared to higher or lower level dancers; possible due to the fact that they are a part of a learning institution (108).
Dancers also seem to be influenced by their dance teachers when developing imagery, and then especially teachers who use metaphorical images in class (106) (108). However; the dancers in the professional group stated that teachers don't normally use the word imagery but ask their students to "visualize", "think through" or "go through in your head" when trying to encourage imagery. This use of terms was found to confuse dancers and they didn't know if the teachers wanted them to mark the movement, physically practice it or use imagery (106). These dancers also stated that at the current time in their carriers instructors didn't use imagery, but in their children years teachers often used metaphorical images to enhance understanding and movement quality. Examples of these were "blossom like a flower" and "open your hands to the sky and see all the stars" (106).

Nordin and Cumming state that imagery should be encouraged in dance, and also that other authors recommend this practice to improve technique and prevent injury. They also state however that the validity of these recommendations have not yet been properly investigated (106).

Donna Krasnow has developed a technique she calls CI-Training, meaning "conditioning-with- imagery training" (109). She states that in today's dance world when one is trying to compliment the classical dance training we usually add either somatic practices, as yoga and imagery, or conditioning practices, as strength training. She states that both these two types of training have clear benefits, and that she in her technique tries to combine the two for best results with dancers (105). Even though this is not a pure imagery technique I find it worth mentioning as this technique states to combined "the best of both worlds".

Krasnow states that dancers today are seeking to improve muscle imbalances, alignment, strength, flexibility and also to perfect technical skills; all believed to prevent injury (105). She believes that the best way to approach all this is to combine neurophysiological work with physiological work; the re-patterning work in somatic processes and the musculoskeletal alterations found with conditioning work (105). This technique however is not fully developed by Krasnow herself. She states in her article that this technique has been developed through learning several different techniques herself, and that the exercises have been modified by her around her 5 basic principles (discussed below). For a full list of where her technique has spun from see the article on CI-Training (105), also available at www.citraining.com (109).

In her article of introduction to CI-Training (105) Krasnow states her technique has 5 basic principles;

- *Integration principle*; the whole body should be integrated to all movements, and this also involves integration of body-mind connection.
- *Increasing principle*; this applies to the progression in difficulty, strength and range of motion and should be both over longer time but also in each session.
- *Alternating principle*; exercises should alternate in muscle strength, muscle endurance and flexibility. There should also be alternation in left/right, agonist/antagonist and upper and lower body work.
- *Specificity principle;* both exercises and imagery should be as dance specific as possible. The authors uses two hypothesis for this principle; "*(1) muscle patterns and balanced muscle function learned in a dance-specific context will more likely relate to muscle use required in dance performance, and (2) imagery that is dance-related will be more applicable with exercises that are also dance-related."*

- *Attentiveness principle*; when working with the exercises attention should also be held at the movement process, timing, breathing and transitions. Not only the exercise itself.

Exercises of CI-Training are as said previously a combination of conditioning and imagery that has been developed by combining other techniques of both these areas. The author has chosen exercises and areas of these older techniques and modified them to dance and made them more specific for dancers of today. This makes this technique more specific and more related to dancers, however, one can of course discuss if "picking and choosing" like this will give the same effects of training as it would when one technique is fulfilled like it was intentionally developed.

Krasnow states that the exercises are done on the floor, with all the benefits of for example ballet floor barrè. These include; (105) "*to develop a kinesthetic sense of movement through the absence of mirror- and teacher-oriented visual images; to experience gravity-assisted movement, especially in new alignment patterns; to encourage lumbo-pelvic stability, especially to support lower limb gestures; to encourage appropriate use and development of turnout from external rotation of the hip, rather than from the use of foot traction on the floor; and to avoid excessive muscular overuse in dancers with poor habitual patterns."*

Even though this technique is based on older techniques the research on the effectiveness of its use in improving technique and preventing injuries is quite low. There is some research on the older techniques but nothing that can directly be transferred to the CI-Training. However, the author state to have had great results in the use of this technique and it is also highly supported in the dance community. The author herself also states that the need for more research is present with both her technique and other techniques that are used as alternative training for dancers (105).

Another technique that has been popular in the latest years is Franklin`s methods of body and mind conditioning (110). Similar to Krasnow`s technique this is also a conditioning concept that includes imagery. Franklin has developed exercises using Thera–Band (www.thera-band.com) and small rolling balls and states to have included the imagery to "*ensure the correct alignment and movement initiation for every exercise*" (110). He believes that forcing correct technique on dancers is not the way to go, but that the focus should be to build technique from the inside to create injury-free dancers.

From his book (110) I have highlighted a few main points that I find to describe his philosophy and technique very well;

- "*Because muscles are strengthened within the coordination that you use them, we first needed to discover better coordination before we strengthened…"(page 1)*
- *"She had been practicing crooked arabesque with her shoulders tensed, so her muscles had become stronger to support crooked arabesque with tense shoulders. For her, exhibiting better alignment and less tension made the movement feel weak because she had become used to compensating for misalignment and tension with strength" (from his practical experience with dancers – page 1)*
- *"If you increase the strength of individual muscles without considering the whole body coordination you cannot achieve better technique. So if you increase the strength in a misaligned body, you will strengthen the misalignment" (page 2)*
- *"The Thera-Band (www.thera-band.com) is ideal for dance-specific strength training because you can use it to apply resistance to a variety of dance movements. But when you strength train using free weights or machine weights, you are most often not performing dance-specific exercises (though training in the weight room can make a dancer feel stronger, and thus it may have psychological benefits). (page 5).*
- *"It may be helpful to begin the mental part of your warm-up on the way to dance class by tuning into the body and scanning for tense areas that could use some coordination or extra attention." (page 10).*
- *"Without the increase in the efficiency with which the nervous system directs movement, muscular strength will not do much good. Misguided muscular strength can actually cause injury" (page 15)*

Even though Franklins technique is quite popular in the dance community this technique also lacks scientific evidence of its benefits and effects. I have not been able to find any research papers focusing on this technique or Krasnow's CI-Training. However you can in my opinion to some degree say that these techniques must have some benefits as dancers all over the world turn to these training concepts for help with injury prevention and improving technique. Dancers must have found some help as this is as widely used as it is. But, to what extent these concepts are more successful than other types of training is yet not researched and cannot be fully discussed for that reason. Research should be done to fully see if it is the techniques themselves that are helpful, or just the fact that these dancers do something at all to improve technique and prevent injury.

These two techniques mentioned are at first glance quite similar, but there are distinct differences between them. Krasnow's technique is usually done on the floor and mostly without any type of resistance to the exercises, except for own body weight and gravity. In my opinion the technique is highly influenced be older techniques as pilates and yoga.
Franklin has developed his technique in a more dance specific manner. Many of his exercises are direct dance movements that are trained with resistances from Thera-Bands. The imagery is also highly anatomic in his technique.

Even though both techniques are conditioning as well as imagery I have decided to talk about these in this chapter of imagery due to the specific and high focus on the images in these techniques. Both authors have an equal focus on both imagery and conditioning in my experience with the techniques.

4.2.2 Pilates

Pilates training as a contribution to classical ballet and dance training has been very popular since the development of the technique over 60 years ago (111), and for this reason I have decided to investigate this methods further. In the 1930s and 1940s the famous, and now iconic, dancers and choreographers Martha Graham, George Balanchine, and Jerome Robbins favored the Pilates technique, and later the whole dance world has benefitted from this technique. It has been stated that dancers were the first to notice this technique and use it for both rehabilitation but also to gain strength and balancing (112). Large dance institutions all over the world today have their own Pilates instructors as part of their staff, and in my experience it is hard to find a dancer who has not in some way trained with the Pilates technique. In the same way you can find that most medical institutions with focus on dance medicine also have Pilates instructors to their staff.

A brief recap of the history of Pilates: (112)

The Pilates technique was developed by the German Joseph H. Pilates in the late 1920. Pilates` life had been full of disease and difficulty and through intense study of Zen meditation, yoga and other "ancient" methods he found how his health improved drastically through strengthening and conditioning. He overcame his physical difficulties, and later in his life became a gymnast, self-defense teacher and boxer in England.
During the First World War Pilates was put in captivity together with other Germans in England. During this period he used his fellow inmates as guinea pigs and developed exercises combining physical fitness, mental acuity and control of breathing to build core

strength and improve flexibility. At the end of the war Pilates was stationed at a hospital for war victims. He brought his theories and technique with him, and used strengthening and movements to improve the state of his patients and shorten the recovery. It was during this time that Pilates also started using springs, from hospital beds, to give resistance in his exercises.

After the war Pilates continued to develop his techniques, now back in Germany. Already at this point he started to cooperate with dancers, and the German military was very interested in him training their troops. As he had no interest in this he, in 1923, moved to New York to start a new life. On his way he met his future wife Clara and they later started their first Pilates studio in New York, in the middle of the dance neighborhood. The dancers of NewYork embraced his technique, and the word spread and more and more people found interest in his exercises. It was during these years that he developed the "Universal Reformer", also known as the pliè-machine, and the technique was now not only based on matt work. In the later years Pilates continued to develop his technique, and also more equipment, and in the 1940 he started to educate Pilates teachers.

> *"I must be right. Never an aspirin. Never injured a day in my life. The whole country, the whole world, should be doing my exercises. They`d be happier."*
>
> *Joseph H. Pilates 1965, aged 86.*

<u>The Pilates Technique and Theory:</u>

Pilates called his exercise regime "Contrology", and defined it as the art of control. He believed that movement is controlled by our will and starts in our core; our "powerhouse". The philosophy of his work is to integrate body awareness into conditioning and improve the whole person through improving strength, flexibility, coordination, tone, muscle control and mental conditioning. He believed balance was the main goal and emphasized how movement from one exercise to the next builds strength from the inside out.

Pilates emphasized individuality and when he was teaching himself he often changed exercises from day to day, and also according to whom his student's were. This might be the reasons for him to develop approximately 500 different exercises. The Pilates method was originally done on mats, but equipment was developed to enhance the exercises. (113).

For Pilates the manner of the performance of exercises was more important than the number of repetitions and level of exhaustion during training (114).
Pilates has developed a few principles for his exercises and throughout the literature they wary from 6 to 9 different principles. Some state that he himself developed 6, and that the rest has been added later (114).

The principles are:

1. Concentration/Awareness
    - Deep concentration to all muscles, joints and movements with deep awareness of oneself is essential in Pilates (113). Often when exercising all our equipment, like TV, music etc, does what it can to distance the mind from the body, but in Pilates we try to achieve the opposite, full concentration to what we are doing at that moment (115). This concentration often gives a meditation effect when mastered correctly, believed to give a positive effects to all areas of life (114). Over time our body becomes accustomed to malalignment, and through deep concentration and awareness we can change these patterns in our mind and then the malalignment can change as well. Without this connection of body and mind, nothing can be changed (115).

2. Centering/Balance
    - Balance can mean many things; balance of mind, body, thoughts, balance as in standing on one leg, balance between muscle groups or balance in the training program. It has been stated that Pilates wanted all of these aspects of balance to be included in the program, and he especially focus on balance between muscles and muscle groups as this has a tendency to cause problems for people (115).
    - Centering is referring the concept of "*body center*", a term often used in ballet, and a vital part of Pilates exercises. The center is thought to be what is above the hips and below the ribs, essentially dealing with our abdominal muscles, or core. In Pilates it is said that pure strength in abdominal muscles gives a support for movement, but control of the whole center gives fluidity of movement from the center. Through Pilates the control of the center is practiced, not purely strengthening. (114). It is said that all movements should be controlled by the center and start in the center (113). The concept of

centering is not new, and can be found in many old eastern techniques as tai chi, aikido and yoga. Martha Graham, iconic modern dancer with her own developed style, uses center as fundamental concept in her technique and it has later been one of the aspects she is most known for; a deep flexion of the trunk (115).

3. Breathing
    - Pilates has been quoted in saying "*Breathing is the first act of life, and the last… Above all, learn how to breathe correctly*". It is believed that the breathing is the first step to reach the neuromuscular system, and in Pilates it is look upon as the fuel that drives all movement. (115).
    - To fully understand the body one must understand the mechanics of breathing, and this is essential to reach good Pilates technique. Breathing is used to stimulate and aid during exercises and also to facilitate relaxation (114) (113).

4. Control
    - When the previous principles have been learned control is the follow up to integrate them all and perform qualitative movements. If movements are easy, as straightening neck to decrease cervical lordosis, or complicated like a *grand rond de jambe* in ballet, the level of control is often the same. Initially learning these movements requires effort and concentration, and once learned repetition, dedication and application decides the degree of control. Doing mindless movements gives low control, and it is essential with this control to prevent injuries. Through awareness and concentration we gain control of our weaker parts and thereby we gain strength and performance (114).
    - Gaining control is a conscious action and can only be achieved through repetition (115). Exercises start simple and increase in difficulty as control is learned (113).

5. Precision and Isolation
    - Precision leads to more graceful movements, and is dependent on the level of control. The term precision is not only concerning placement of body, but also the speed of the movement and the coordination with other aspects of

exercises, as for ex breathing. Often in Pilates breath in synchronized with movement, and if you for example are to raise hands above head with breathing in, and the precision is not good, the last degrees of lifting hands you would have to hold your breath. This movement will be without precision, and often feel more stressful then helpful. (114).

- With precision you can achieve isolation of muscles, something stated as being important in the fitness world. When working with apparatus to isolate muscles we do isolate them, however no active control is taken and without the machine this precision of work, or isolation, cannot be reached (115). In the opposite manner; when you achieve isolation your precision is improved. Isolating weaker muscles or muscle groups is especially important, and it is thought to be a highly mental ability. (114).

6. Flow
    - Flow, or continuation, of movement is important in Pilates both in regard to moving from one position to the next within exercises, but also the sessions as a whole. A continual flow of energy like they practice in Pilates is often seen when watching professional dancers, swimmers etc; an effortless continuation and flow of movements. Physiologically speaking flow deals with timing of muscle recruitment (115).
    - When muscles are in flowing motion it is believed that they are toned. When you are able to achieve flow during Pilates training, you will also be able to have flowing movements when not exercising as well (114).

Other aspects also often added are "*be efficient*"; meaning isolation of muscle use to save energy and limit accessory actions (115). "*Seek harmony*"; meaning a whole and complete effect of the training; walking from the class feeling rejuvenated, centered, in control, aware of each muscle and sensing the depth of ever breath (115). "*Routine*"; meaning to establish an individual and effective exercise routine (114), and some state that first principle is "*relaxation"* (113).

When starting Pilates training mastering all exercises with all the principles is very difficult. Often it is said to be best to start with one principle at a time and work ones way through them all until all of them can be applied at once within all exercises (114)

Pilates and Dance:

As mentioned previously, Pilates is used extensively in the world of dance, possibly due to the similarity between dance and Pilates; both having focus on body control, precision and fluidity of movement (116).

Research on effect of the Pilates technique have been stated to being mostly concerning dancers, and especially their use of the technique for rehabilitation and conditioning (116). However, the amount of research is quite low compared to the enormous interest and use of the technique (117). All the research that is done involving dancers is not accessible to me, however three review articles from 2006-2007 looks at all the present literature and discusses the outcomes and status of the research.

Shedden and Kravitz (116) looked at 6 articles relating to Pilates and dancers, and conclude that research on the topic is inadequate and has too many flaws to make any sound conclusion on the effects of Pilates in dance. They state that lack of adequate controls, low reliability of instruments used for measurements and improper statistical analyzing makes the present research invalid and that it doesn't really give any reliable information.

However the researches themselves state that they had results in their work;

McMillan et al. (118) conducted an experiment to see if there were any changes to dancers dynamic posture during a grand pliè after Pilates training. They found decreased body sway and improved body alignment during the grand pliè after Pilates training and conclude that this training improves dynamic body control due to its emphasis on spine stability. However, both Shedden and Kravitz (116) and Bernardo et al (111) state that the research includes several flaws and that the results are colored by that. The flaws mentioned include; inadequate control of the training intervention (111) (116), and lack of subject characteristics (111).

- Parrot conducted an experiment in 1993 (article not accessible to me), that is review by both Bernardo et al (111) and Shedden and Kravitz (116). He examined the effects of Pilates on dance technique and esthetics, and found that the Pilates technique improved body alignment, intention of movement and body expression (111) (116), and he concluded that Pilates as conditioning technique for dancers may improve both technique and esthetic (111). However both of the reviewers mention several faults of

the research; erroneous statistical analysis (116), lower inter-rater reliability (116) and also the fact that they do not specifically specify length of training period (111), only speculating it to be 8 weeks long.

In these two reviews many of the same articles are looked at, and in both articles one can find the same type of conclusion; there is need for more research. Bernardo et al (111) states that there is weak support for the effects of Pilates but states that this might be only due to the lack of proper investigations. Shedden and Kravitz (116) also state that the evidence for effect of Pilates is very low and that there is need for a well designed research design to prove the claimed benefits of the Pilates technique.

Bernardo (117) reviews three experiments on non-dancers and also conclude that evidence is low due to the lack of proper study designs.

4.2.3 Strength Training

In the dance world the topic of strength training seems to be a "soft spot" that his highly discussed. There seems to be some disagreement between the dance professionals and the researchers, having contrasting beliefs and thoughts on the area. The main issues for discussion seem to be, as previously discussed in this thesis, involving the combination of art and athleticism.

Koutedakis et al (102) state in their review article of strength training related to dancers that research has reveled that dancers are not as physically fit as equivalent athletes, and then especially with respect to muscular strength.

In the dance profession on the other hand there have been concerns that focus on strength training, rather than artistic elements, may damage the art form and decrease the dancer's esthetics and flexibility, two of the main aspects of dance (102) (103). For this reason strength training has been viewed upon as "*not necessary*" in the dance world (102).

It is possibly due to these views on the topic that it is hard to find relevant articles in this area. Koutedakis et al (102) state that little research on the effects of strength training on dancers exists; Brown et al (101) agree, but add that effects of strength training has been well documented in other areas of sports medicine, and in the general population.

Brown et al (101) state the following;

- *Strength, defined as the ability to exert maximal force, is essential for the slow, controlled movements in dance such as developpè and grand rond de jambs.*
- *Power, described as the ability to exert force quickly, is vital for effective jumps in dance.*

Increasing muscular strength is based on the concept of overload, and with the daily training of dancers most often being below the threshold for overload there is usually no improvement in strength when only performing traditional dance training (102) (103). This would point to the need of some additional training if strength is to be improved. However, providing the dancers with exercises that are mechanically similar to dance specific movements is necessary (102).

Strength can be described as the maximal force a muscle can produce in a voluntary contraction. In dance most movements are slow and last for a few seconds; hence the time of contraction is prolonged. It has been found that dancers mostly have slow muscle fibers. (102).

Koutedakis et al (102) state that even though dance professionals tend to believe that strength training equals loss of flexibility there is no evidence that this is true; in the same way increased muscle strength may not always lead to an increased muscle size. However they recommend working through full range of motion to prevent shortening. With research showing these results, one could questions if the statements from dance professionals regarding loss of flexibility etc hold ground or if they are outdated myths. Rafferty (103) as well found that strength training has been found by several researches to have highly positive effect on dancers, and training with exercises that stimulate plane, direction and angle of the dance skill is especially efficient. She concludes that the concept of strength training has been misunderstood in the world of dance, and that the assumptions from professionals are not supported by research.

Koutedakis (102) refers to several older researchers and states that dancers have been found to have lower torque values then other athletes. Ballerinas are said to have the lowest muscular strength, with only 77% of the weight predicted strength values based on normal values. They state that these results may be due to the fact that dancers have mainly slow muscle fibers and also that skeletal muscle only accounts for 38-43% of their body weight. Modern dancers on

the other hand have been seen to have more strength than ballerinas and can in many cases be equal to other athletes.

Research on strength related to injury shows that the lower the level of thigh strength, the greater the degree of injury (119). Researchers conclude that supplementary strength training may be a cost-effective way of reducing dance injuries.

Brown et al (101) refer to research that has shown how a low intensity strength program designed to improve hip flexor strength gave an increase of six inches in the height of a leg extension a la secondè (the combined hip actions of flexion, abduction, and external rotation). Concluding that supplementary specific strength exercises may be helpful to improve dance technique abilities. Brown et al (101) themselves conducted research on the same topics, and found that strength exercises gave a subjectively perceived improved jumping ability. However they state that due to the mainly esthetic principles of dance it was difficult to measure if, or how, the improvement in strength affects the technique and esthetics.

4.2.4 Cardio-respiratory Fitness

Howse (19) states that keeping proper cardio-respiratory fitness is important for prevention of injury. It is generally believed that fatigue is a common cause of injury (11), and commonly lower levels of cardio-respiratory levels are associated with fatigue (103); due to the lower ability to recover between high intensity bouts of exercise seen in dance (120). When you are fatigued the ability to perform skills correctly is diminished, and an injury is more likely to occur (120).

Twitchett et al (120) state that ballet is a "*high -intensity, intermittent form of exercise for which a good aerobic foundation is required. Poor aerobic fitness levels may be an underlying source of injury in dance, due to the effects of cumulative fatigue".* They conducted a research where they investigated the relationship between aerobic fitness, body fat percentage, strength and flexibility to injury occurrence and nature. After their research they concluded that aerobic fitness was significantly correlated to the number and nature of injuries in female dancers, and state that their finding support the previous belief that dancers do need a good level of aerobic fitness to both perform well and minimize injury risks. They also found that lower levels of body fat percentage in the same way is related to injury occurrence and nature of injury; dancers with lower levels of cardio-respiratory fitness and/or lower levels of body fat percentage are injured more often and have longer time of recovery.

I do not have access to previous, or other, research on this area, however; Twitchett et al (120) state they their findings correspond to other studies done in this area of research.

Rafferty (103) states that the dance class itself *can* give a moderate increase in aerobic capacity, but when the levels of training continue over same intensity as often seen in dance, adaptation to the stimuli occur giving no or little progression. She highlight research done that have found both the warm-up and center phase of the dance class to have to low intensity to elicit any training effect. She suggest changing the patterns often used in warm-up and center to include more repetitive movements with higher intensity and with less rest time to allow an aerobic foundation to develop.

Most research is done one the ballet dancer, and ballet class, however; Wyon at al (104) conducted a study where they investigated the physiological responses to a modern dance class. They found that the modern class gives the same physiological responses, as heart rate and oxygen uptake, as the ballet class. They also state that to increase the aerobic cost of a dance class the workload needs to be increased, especially during the warm-up. They found that the center phase of the modern class is sufficient to keep the heart rate at optimal level.

As it is usually fatigue that is listed as common cause of injury, one can discuss for what reasons the fatigue is occurring; poor nutrition, poor aerobic capacity or possibly to little rest between exercises? I have not been able to find research directly related to this area, trying to identify direct cause of fatigue, but in my opinion all arrows point in the direction of a combination of all these factors. Twitchett et al (11) investigated the demands of a working day on dancers, and how much time is spent in resting between trainings. They concluded that dancer had less then 60 minutes "at rest" during the day, and that this possibly can play a role in development of injury through development of fatigue. They stated how the result of this study may be useful in preventing injuries if dance schools reevaluate the schedule for the dancers.

As with other aspects of dance medicine, the area of prevention also seems to need a multidisciplinary approach. To remove the fatigue as a risk factor both aerobic fitness, nutrition and rest between trainings needs to be improved.

Rafferty (103) also states the following; "*it may no longer be necessary to ask if fitness should be included in a dancers training, but how it can be holistically implemented to best effect"*

5. Findings

In this chapter I will summarize what I have found during the writing of this thesis to answer my investigative questions stated in the beginning of this work. As this work has been a literature review, and not a research study, there are no specific results to my work. All statements are referenced previously in this work in the respective chapters.

5.1 What are the most frequent injuries of lower extremity in dancers?

Epidemiological research on the topic of dance injury is mainly through screening processes at either dance institutions or health institutions dealing with dancers. The research usually only state site of injury and not as often what specific diagnosis is more frequently found.

The rate, severity and occurrence of injuries in dancers are found to be hard to evaluate as dancers tend to not report "minor" problems to health personnel, and also continue or return to training before ending appropriate rehabilitation or therapy. The screening processes that often are used have also been found to have several weaknesses; it is often difficult to clearly define what an injury is, and dancers have a tendency to underreport their health problems.

However; the more common site of injury is found to be the lower extremity; compared to trunk and upper extremity. The foot and ankle are more often injured; compared to other sites of the lower extremity. Ankle sprains are the most commonly mentioned injury. Overuse type of injury is more frequently seen compared to traumatic injuries. The severity of dance injuries is often classified as mild to moderate. The time loss and functional disability however is often severe.

- For a list of study-results on injury frequencies from 1983-1998 see Appendix 1.
- For a list of resources supporting that that lower extremity if more frequently injured, that the overuse type of injury is more common, and that foot and ankle injury is more common see table 1 page 21 of this thesis.
- Lists of common injuries according to Harkness Center for Dance Injuries can be found in Table 2.
- List of discussed specific diagnosis in this thesis, and also commonly discussed diagnosis elsewhere in dance medicine literature, can be found in the respective chapters; Hip Injuries, Knee Injuries, Foot and Ankle Injuries.
- More on this topic is found in this thesis chapter 2.1; Epidemiology of Dance Injuries.

5.2 What are the main reasons for these injuries to occur?

Howse (19) states one can classify the causes of injuries into 5 groups; anatomical restrictions, knowledge of dancers, bad teaching, poor application of technique and environmental factors. Solomon et al. (20) state that most dance injuries come from a bad circle originating in faulty movement patterns. They state that an unprepared body who tries to deal with heavy technique tends to develop faulty movement patterns manifesting itself in improper muscle sequencing, misfiring of unneeded muscles, overuse of certain muscles and muscle tone imbalances. This will give you all the ingredients of injury development.

Technical faults are believed to be highly connected to injury development. The typical technical faults that are mentioned in this text that contribute to injury development include; forcing turn-out, hyperextend knees, rolling in of feet, incorrect weight-bearing. In addition improper landing technique and improper warm up or class progression is often mentioned. Overuse and "wear and tear" causes are more common compared to traumatic incidents.

When dealing with the specific diagnosis all the causes of them have been summarized in Appendix 4. This scheme lists the causes of all the mentioned diagnosis in chapter 3. Below I have summarized the most important findings from this scheme to have a better overview of the specific causes of dance injuries.

From the diagnosis I have written about in this thesis, a total of 16 diagnoses, 3 are in hip, 3 are in knee and 10 in foot and ankle.

Of the total 16 diagnosis;

- 12 of them list that technical errors in general are the possible cause
- 10 of them have listed anatomical variations as possible causes
- 9 list excessive foot pronation and a possible cause
- 8 of them lists forcing turn out as a cause, and one weakness of external rotators of hip
- 6 of them list environmental factors as footwear or floor construction
- 6 have listed one of the other injuries as predisposing factors
- 6 have listed muscle weakness as a factor. The muscles include; hip abductors (2 diagnosis), external hip rotators, hip adductors, Vastus Medialis, peroneal muscles (2 diagnosis), intrinsic feet muscles(2 diagnosis), Gastrocnemius, quadriceps, hamstrings and Gluteals
- 6 have listed trauma as cause of injury, including faulty landings from jumps

- 4 list biomechanical malalignment as causes of injury
- 4 have listed pliè as a possible cause
- 3 list muscle imbalances; around knee, between adductor hallucis and abductor hallucis longus and between dorsiflexors and plantarflexors of foot
- 3 have listed tightness of Illiotibial band, and one diagnosis lists weakness of thigh adductors and Vastus Medialis giving a lateral pull at the knee as possible cause
- 3 have listed problems with relevè as a possible cause
- 2 have listed hyperextension of knee as possible cause
- 2 have listed inadequate warm up
- 2 have listed arthritis and 2 have listed sacroiliac disturbances

5.3 Are the injuries in any way connected to each other?

There exists no research trying to connect injuries to one another. There is however found similarities in the causes of injury development, seen in the question above. More about this in the chapter of discussion.

5.4 What are the different possibilities for active prevention of them?

Prevention of injury is the main focus in the field of dance medicine, contrary to this however there is a surprisingly small amount of research on ways of prevention. There is a clear agreement amongst authors that prevention is best approach in a holistic matter, and Howse (19) state that prevention can be reached through; development and maintenance of good technique, development and maintenance of muscle strength and joint mobility, preservation of cardio-respiratory fitness, good nutrition and assessment of students before starting professional dance schools. I choose to look at techniques corresponding to these points, and have previously discussed education, screening, imagery, pilates, strength training and cardio-respiratory fitness.

Screening has been found to prevent injury, and also aid in the advancement of research through establishing norms for various parameters. There are two basic types of screening; physical screening and survey type of screening. Benefits of screening processes include detection of risk factors at an early stage to prevent injury development, to learn body characteristics of dancers that can be used as a baseline for comparison when injury occurs and to collect data for use in research to distinguish between what is “normal” and what is deviation. In addition some legal benefits are mentioned; protecting institutions from legal claims from inured dancers, and protecting dancers from demanding teachers or choreographers.

Physical screening is recommended at the entrance into professional dance schools and companies to prevent injury through early detection of risk factors. There has also been a proven decrease in injury occurrence in a professional dance company through pre and post season screening (97). An example of a screening sheet that can be used for physical screening can be found in Appendix 2.

Education of dancers is according Solomon et al (20) e key point in prevention; with a goal of enabling dancers and teachers to early detect precursors of injury. A screening study done on pre-professional dancers (98) also reveled how their general knowledge on safe dancing was quite poor and the authors highlighted the need for education of these dancers to ensure safe dancing in regard to general health; as menstrual cycles and eating habits. Studies on education of dancers have also shown that it can be very effective in preventing eating disorders and enhancing dancers knowledge on the topic of diet. A DVD based program of dancers (99) showed how through a brief educational DVD the dancer's knowledge was increased and their perception of own eating habits were changed.

Specific techniques outside of dance have been used for several years with the goal of preventing injury and enhancing skill development. It has been suggested that the high level of injury incidence in dancers is related to the found levels of low overall fitness of dancers. The question in the research environment has been if the dancers at all are physically prepared for the demands of today's dance training. Some research has found that the traditional dance class is not sufficient for dancers of today, and recommends either changing the dance class structure of adding supplementary training. The techniques that dancers chose are typically in two different groups of training techniques; conditioning techniques, or somatic techniques; "body-mind therapies".

Imagery is often used in dance-teaching, and it has been found that most dancers use this skill during their training, and that the higher levels of dance the more use of imagery. There is a general recommendation to encourage the use imagery, the validity of these recommendations have not be verified or properly investigated. Popular techniques as CI-Training and Franklin method are stated by the authors and dancers to be very effective in preventing injury through improving strength, movement patters and awareness. The effectiveness of these techniques are not at this point proved scientifically.

Pilates is very popular amongst dancers, and dancers were also the first to embrace this as it was developed over 60 years ago. According to Solomon et al (20) Pilates is a good way of learning control of core muscles, and with a focus on body control, body awareness, balance, flow, precision and breathing. Even though the technique is used worldwide, and it is quite old, the amount of proper research is surprisingly poor. The studies themselves are not accessible to me, reviews however state that more research is needed as all previously done studies have too many flaws to give any proper results regarding effectiveness.

Strength training is a widely discussed topic in the world of dance; dancers are found to be weaker than other athletes of same level, but dance professionals are worried that increased strength will decrease the art forms esthetics and dancers flexibility. Due to the skepticism toward strength training there is a low amount of research on the topic, the people who do research on the topic however state that the skepticism and believes of dance professionals toward strength training is not supported by any scientific proof, and that strength training done through full range of motions does not affect flexibility and that an increase in strength does not mean an increase in muscle size. Research has shown that dancers have mostly slow muscle fibers, and that ballerinas have quite low muscular strength; only 77% of the weight predicted strength values based on normal values (102). Other researchers have also found that the lower the levels of thigh strength values, the greater degree of injury (119). Research done on strength in relation to improvement of technique (101) has shown that target specific strength training improved height of a leg extension a la secondè, and also the jumping ability. The authors state however that measuring if esthetics were affected was not possible.

Cardio-respiratory fitness is also mentioned in the above list by Howse. It is generally believed that fatigue is a cause of injury to dancers, and fatigue is generally believed to come from poor cardio-respiratory fitness. The dance class itself is believed to give a moderate increase in aerobic capacity, but as the dance class is often repeated there is a large adaptation to the stimuli giving little or no progression. It has been found through research that female dancers with low levels of cardio-respiratory fitness and low body fat percentage have experienced more injuries and also have longer time of recovery after an injury.

6. Discussion

In this chapter there will be a discussion around the findings I have done throughout this thesis. My own thoughts and opinions about these different topics are stated here, and my own interpretations of my findings.

6.1: What are the most frequent injuries of lower extremity in dancers?

For me it seems that the main issue when dealing with epidemiology is the previously mentioned mentality of dancers to avoid medical personnel, and in general avoid dealing with injury. As stated in the chapter of mentality; dancers have a tendency to underestimate the severity of their own injuries, and also handle them according to that evaluation. This causes a problem and the research environment is afraid that many injuries are underreported; hence today's research not properly showing the reality of injury occurrence.

It seems from the literature of today that there is a wide agreement that lower extremity and foot and ankle is most often injured. However; it has been quite hard to locate research from the latest years, and most of the research has been locked and unavailable. This has given me some problems in my searches, and I have had to depend on authors citing older articles. It also seems that epidemiology of injury occurrence is largely based on different authors clinical experience.

Proper screening and injury reporting seems to be a need; and a main problem with this is as mentioned previously how injury is to be defined, and most importantly who is to define if an injury has occurred?

From my own experience with dance it seems logic that the lower extremity, and the foot and ankle, are mostly injured. The characteristics of classical dance with o lot of "extreme motions" of the legs, especially turn-out and pointè, will in my opinion of course affect this part of the body the most. Also as mentioned previously many of the classical dance style focus on a rigid and stiff torso, whilst legs are doing more of the "extreme" work.

6.2: What are the main reasons for these injuries to occur?

Regarding the general causes of injuries:

As seen from the previous chapter "findings" Howse (19) has classified causes into 5 groups; anatomical restrictions, knowledge of dancers, bad teaching, poor application of technique and environmental factors. Point 2-5 can be changed by the dancer, the first point however will have to be respected and worked around. It is this first point however that has a tendency to cause problems; these anatomical restrictions are often *not* respected by dancers, or

teachers, often leading to dancers pushing their body beyond its limits, hence causing an injury. This is especially a problem when dealing with flexibility and turn out.
These five points I view as quite important when dealing with prevention as one can see that 4 out of 5 points can be worked with and changed to prevent injury from occurring. If Howse is correct in his theory that all injuries originate from these points of causes, one can be very successful in preventing them by improving dancers and teacher's knowledge, improving technique and securing environment when in the studio, on tour and on stage. He also quite drastically state that all dance injuries originate from technical faults. This statement is widely supported by the whole dance medicine environment. The statement mentioned from Solomon et all regarding the "bad circle" also corresponds largely to this, and can in my opinion be dealt with correcting the technical faults and the postural faults of the dancer.

The typical technical faults that are mentioned in this text that contribute to injury development include; forcing turn-out, hyperextend knees, rolling in of feet, incorrect weight-bearing. In addition improper landing technique and improper warm up or class progression is often mentioned. From my own experience with dance, and also through observing several dance classes, I know that all of these faults are very common, and often one dancer exhibits several of them at once. Many dancers also find it difficult to observe in themselves all this aspects at once, and controlling all these habits at once.

Regarding the specific injuries and their causes:

As the injuries seen in dancers in general are found in many different types of sports the reason for them to occur specifically to dancers is the most important issue when trying to prevent them. As we can see from the list of causes in Appendix 4 the anatomical individual variations is present in almost all the injuries. This is in my opinion an important fact, as this point to the importance of each dancer to take care of their own body, and dance within their own limits; something requiring knowledge on your own body, and also anatomy in general.

Further on this list one can see how technical errors are highly present as cause of injury, including turn-out, pliè, relevè, foot pronation and incorrect landing techniques. This point however is changeable compared to the anatomical variations. We are able to affect this aspect of the 12 diagnosis who mention technical errors as possible cause. Teaching proper technique and also educating both dancers and dance teachers in the dangers of faulty technique will be important. Enabling dancers to see their own mistakes would in my opinion be a first approach to this. Not all dancers are aware off the technical faults, or not able to see

them or feel them I their own body, and they often don't have the knowledge about the damage it may cause.

Muscle imbalances, faulty biomechanical alignment and weak muscles are also aspects that we actively can change. In what way they can be changed however can be discussed. As seen in the chapter of prevention there are several ways of dealing with these problems, possibly equally effective, but in my opinion an individual approach to each dancers will be important no matter what type of approach one will choose. Postural faults and weaknesses are seldom the same in people, and an individual screening and individual approach to exercises and treatment will be the optimal way of handling this. Again I find that it can also be helpful to educate the dancers in postural faults and biomechanics for them to be able to detect this in themselves.

Footwear and floor construction is to some extent changeable. However, the shoes worn in dance are seldom with any shock absorption function as discussed previously in this thesis. However, floor at dance studios have often been seen to be custom made with shock absorbing function, trying to compensate for some of this. Floors are as discussed a very important aspect of dancers prevention strategy, and the main problem is usually floors and stages when on tour or doing shows. To what extent one can change this is possibly limited, it is however in my opinion important for dancers to be aware of these problems for them to be able to take caution; again pointing to the importance of educating dancers about prevention and injury.

6.3: Are the injuries in any way connected to each other?

As stated in the chapter on findings I have not been able to find any specific research trying to link injuries together. One can however, to some extent, say that all the injuries discussed in this text to some degree are connected to each other through faults dance technique.

As these mentioned injuries have a high prevalence in dance, and so many of them have similar etiologies I can see how one technical error may produce several injuries, possibly like a chain reaction. When looking at the list of causes of injury (Appendix 4) I see a pattern of injury development. One example can be using the most common technical error; the turn out: Weakness of external rotators of hip are causing problems in holding the turn out, compensating for this with screwing the knees leads to another compensation with pronation of the feet. Only this "small" chain could in theory produce injuries to the whole lower extremity. When this additionally is coupled with the unbalanced knee joint often seen in

dancers with tightness of Illiotibial band, weak adductors and Vastus Medialis and hyperextended knees you have a situation where an injury in my opinion is impossible to avoid.

As dance is a dynamic and whole body activity one small change in the patterns of movement of one joint will drastically affect the whole chain of movements. If the dancer is experiencing pain or a problem in the hip, it is likely that the mechanics from the hip toward the lower leg will change and affect the knee and foot. This is seen in people who do not dance, and from my experience this kind of chain reaction is often enhanced in dancers as they use their body in a quite dramatic way with movements often at extremes of joint ranges of motion.

When I was lecturing at Langhaugen Dance High School about this topic the dancers were largely surprised by how all these injuries has common causes and often were coupled. This tells me that the knowledge about their own body, and especially movement patterns and chain reactions, is quite low compared to the body control these students often exhibit. They are often able to locate and detect the smallest changes in their body, yet they are not aware of the dangers small problems can have to their whole movement system. After conversations with dance teachers, and from my own experience as a dance teacher and student, I know that there is placed a lot of focus on body control and body awareness in dance teaching. There is enormous pressure to detect the activity of small deep muscles, and to be able to actively choose what muscles to use; however, there is surprisingly little knowledge on the effects of these small things and changes. I would assume that with enhanced anatomical knowledge, and basic kinesiology, these aspects could easily be changed. If you are more aware of how everuthing works and looks anatomically my logical interpretation would be that the practical aspects of it would be easier as well.

6.4: What are the different possibilities for active prevention of them?

As mentioned in the chapter of findings prevention seems to be everyone's main goal in dance medicine. In my opinion Howse (19) summarizes a nice approach to prevention; development and maintenance of good technique, development and maintenance of muscle strength and joint mobility, preservation of cardio-respiratory fitness, good nutrition and assessment of students before starting professional dance schools. Using all these points and trying to fulfill them would to a large extent give the holistic approach that I would prefer, and that I think would be most suitable. Trying to get a look into how to fulfill all these points I choose to

look at techniques I think corresponding to these points. I have therefore discussed education, screening, imagery, pilates, strength training and cardio-respiratory fitness.

Screening has been found to prevent injury through early detection of injury precursors, and also aid in the advancement of research through establishing norms for various parameters; both important factors. Physical screening processes have in my experience been more and more wide-spread the latest years, and with the development of screening forms and routines this seems to be a solid development. Now there is usually a routine screening of dancers entering higher levels of dance education at universities, but high school dance programs however seldom have any routines like this. In Norway, where I have my experience from, this type of screening routine is not common at the high school level of dance training, even though the training frequency and load often is very similar. Not all higher levels of dance education offer this in Norway, and I can see how this highly depends on finatial aspects of the schools.

Education of dancers seems to be a reoccurring topic for me when writing this thesis. I feel that in a large extent both screening and education of dancers can be an early prevention tactic especially in dance students perusing a career in dance. Giving them proper and dance-specific knowledge of anatomy ad kinesiology will to a large extent give them the opportunity to detect their own weaknesses, and handle them thereafter. I see it as highly necessary for both correct development of technique, and also to give young dancers a fair shot at pursuing their careers. Many young dancers train hard to achieve what they want without knowing how to take care of their bodies at the same time. Without proper knowledge their career might end suddenly and to early.

There is however an important question of economics involved in the process of screening and education. To be able to give the dancers the benefits of these processes money must be spent, and to be able to follow up what is found in the process even more money will have to be spent. As the dance community often does not have excessive amounts of money I can see how this might be something that is overlooked to save money. There is in my opinion the option of workshops, pre and post season programs or other short term situations where a lot of the benefits of screening and education will be possessed without having to employ full time health professionals. This is also shown by the DVD-approach used in the research stated in the chapter of findings.

Specific techniques outside of dance have, as mentioned, been used for several years with the goal of preventing injury and enhancing skill development through attacking the statements that the high level of injury incidence in dancers are related to low levels overall fitness and strength. Logically enough dancers seek other techniques when researchers have questioned whether the dance class itself is sufficient. The techniques that dancers chose are typically in two different groups of training techniques; conditioning techniques, or somatic techniques; "body-mind therapies".

When looking at the techniques that dancers choose it is quite interesting to see how they have a tendency to choose techniques with similar characteristics as dance. This is quite positive in regard to the esthetic aspects, and I also believe that for best effect the training that will supplement dance training should be similar to the muscle use and muscle coordination of dance. We know that muscle function and muscle coordination is highly dependent of what type of work the muscle is used to perform, and changing the type of training completely might not be as beneficial for dance purposes.

Imagery is often used in dance, either intentionally to teach something, or unintentionally as an internal process of a dancer. Concepts of pure imagery are not found that often, but concepts combining imagery with conditioning is very popular now a days. CI-Training by Krasnow (105) is one concept like this that has been reviewed in chapter 4.2. This technique is widely used by dancers to improve technique, enhance strength and improve movement patterns. It states to be a combination of somatic and conditioning practices, extracting the benefits from both yet being more dance specific. It is a combination of neurophysiologic work and physiological work according to the author, and since the work is done on the floor it states to have the benefits of a floor barrè; develop a kinesthetic sense of movement, experience gravity assisted movement, encourage lumbo-pelvic stability, encourage appropriate use and development of turn-out from external rotation of the hip and avoid excessive muscular overuse in dancers with poor habitual patterns. Even though this technique is based on older more researched techniques specific research around this technique is missing. And one can discuss whether the research from the older techniques can apply to this as the author has been "picking and choosing" from all of them, and changed them to be more dance specific. A plus however is that the developer of the technique herself is a dancer with wide experience in dance medicine, stating to have excellent effect in improving technique and preventing injury. The technique is my opinion combines

conditioning exercises successfully with imagery and dance specific muscle work and coordination.

Another conditioning technique including imagery has been developed by Franklin (110). In comparison to CI-Training this technique does not only work on the floor without resistance, but the exercises are often dance-specific positions or exercises using Thera-Band for resistance. In this way you are training specific dance movements against resistance while using imagery to ensure proper technique and muscle use; thereby using the same muscle coordination as with the dance movements and not changing the function of the muscles from the dance training. Franklin states to emphasize building technique from the inside with the use of his images, and not forcing dance technique on dancers. In his technique there is a clear focus on muscle coordination, movement patterns and awareness of muscle use. As with CI-Training this technique is also lacking scientific proof of its effectiveness, both of them however have state to have been very successful in preventing injuries.

Regarding both of these techniques one can also discuss their differences and how they will differently effect the dancers; if the use of floor exercises in the longer run will be beneficial as this position offers little resistance and thereby little improvement in strength; as the dancers mostly work in standing position. If possibly this technique will be more focused on the dancer's ability to imagine the correct positions and mentally practice them, and not as much improve their ability to perform them in standing? On the other hand, the use of resistance might give the dancers strength they possibly "won't need", and exercises against resistance might often cause an increase in difficulty thereby increasing the risk of performing it the wrong way; possibly needing constant supervision or use of mirror, and good knowledge on small patterns of movement.

For me as a physiotherapist I can clearly see benefits of both of these techniques. I like how they both have a large focus on imagery as I believe this is important in understanding of technique, and also the dancer's ability to perform this correctly. Exercises on the floor are in my experience very effective with dancers who experience problems in performing basic technique as turn-out from the hip and controlling their hip position when legs are lifted. The supine position offers an easier way of training this awareness as it eliminates other aspects you have to consider while in standing. There are however, in my opinion, little improvements in strength while working on the floor. If the dancers are experiencing lack of strength the need for some small resistance is needed in my experience. Even though some

very experienced dancers are able to actively train their muscles by only imagining heavy resistances and actively contracting their muscles as if with resistance. What effect this has however is not explored.

When dealing with imagery I have from my own experience seen how this is much easier to do when there is some knowledge on anatomy. When you are able to imagine the insides of joints and how they are functioning I find it easier to actively control the smaller movements. My personal imaging skill, and also dance technique, improved drastically after I was taught anatomy. With smaller children however anatomical imagery is not necessary, and visual pictures are often effective.

Pilates is very popular and with a focus on body control, body awareness, balance, flow, precision and breathing it has clear similarities to dance training; possibly being the reason for dancers to favor this technique, and possibly also why many feel it aids their dance trainings so well. Even though the technique has poor scientific proof to its effects there must in my opinion however be some positive effects of this as it throughout the years has been the favorite supplementary technique amongst dancers and they all state it improves technique and prevents injuries. Can it possibly be that the fact that it is a "mind-body" technique with highly mental aspects that the effects are hard to find in a measurable manner? That dancers feel improved control, either physically or mentally, without possibly to be measured?
From my own experience I have felt that the technique gives improved movement awareness and control, and there is also the fact that the technique has several similarities to dance; making the muscle work similar to dance movements. It is also a thought of mine that it might be easier to prescribe this type of exercise to a dancer in need of conditioning compared to something with fewer similarities in movement type to dance; something to possibly keep in mind when dealing with dancers.

Strength training is as mentioned widely discussed and dancers have been found to be weaker than other athletes of same level. Dancers and dance educators however are skeptics as they are afraid increased strength training will negatively affect the artistic and esthetic aspects of dance. One can however clearly see from the research that dancers could benefit from strength training, and possibly the questions lies in what type of strength training should be applied. All authors recommend working through full ranges, and state that flexibility and muscle size does not need to be affected; removing the concern for development of bulky muscles. In my own opinion strength training using machines and isolating muscles would logically seem less

useful for dancers as it practices another type of muscle function, and movement pattern in a joint. The skepticism toward this type of training in regard to muscle size is proven to be wrong, however the aspect of muscle functioning and coordination still applies. I believe that training within same muscle coordination and joint coordination as in dance would best affect dancers in a positive way. Working against resistance in more dance-specific movements would clearly have benefits when looking at this research. Knowledge on what to strengthen and what not to strengthen however is necessary.

Rafferty (103) has been quoted previously in this thesis saying; "*it may no longer be necessary to ask if fitness should be included in a dancers training, but how it can be holistically implemented to best effect.*

It also seems to be largely on the basis of "what is best – strength training or stability training", where one of them is known for long lean muscles, and the other often with bulky stiff muscles. As mentioned, researchers advocating strength training highly emphasize the use of dance specific movements and specific exercises mechanically similar to dance, then removing these bulky characteristics. If strength training is performed in dance specific movements I would assume that one to a larger degree would be able to control how the esthetics are affected, and one would also be able to target specific areas of problems in technique. From my understanding the difference between strength and stability concepts would then evolve around the use of resistance; stability concepts mostly using body weight and strength training using some external source for resistance to reach levels of overload in the muscle.

As mentioned it is generally believed that fatigue is a cause of injury to dancers, and fatigue is generally believed to come from poor cardio-respiratory fitness. It has been found through research that female dancers with low levels of cardio-respiratory fitness and low body fat percentage have encountered more injuries and also have longer time of recovery; hence the cardio-respiratory fitness must be important in prevention of injury.
Through reading different articles on this topic however I see that there are several aspects to discuss regarding this topic. As it is fatigue that is cause of injury often associated with the lower levels of cardio-respiratory fitness one can discuss if possibly there exists other causes as well giving fatigue among dancers; they have also been found to have poor nutrition, low

levels of body fat and a working day with limited time at rest. One can wonder if the fatigue is not only from the low cardio-respiratory fitness but a combination of all these aspects.

Looking at all these different aspects of prevention one thing stick to my mind; there seems to be a large need for a holistic approach to the prevention of dance injuries, and in my opinion the approach should including all the points from Howse`s list. Improving the dancer's knowledge on technique, injury and anatomy, screening dancers regularly for risk factors, improving their strength, movement patterns and awareness and facilitating cardio-respiratory fitness and proper eating habits. In what way this is possible to do can of course be discussed, and the economics of it is difficult. It is however an investment in the future, and may limit the amount of cost dealing with injuries.

7. Conclusion

To conclude with anything after writing this thesis is quite hard. I have chosen a wide topic with the intention of giving myself a broad specter of knowledge that I for sure will be able to use practically in the future, in my work with dancers. By choosing such a wide topic, compared to a smaller detailed research based topic, I believe I have given myself the opportunity to have a more holistic view of dancers and their health problems, providing me with my base when entering my future work. A disadvantage however with this type of topic is that concluding, or finding specific results, is quite hard. I would however in this final chapter like to emphasize what I feel remains as main points from my time writing this thesis and diving deeply into the world of dance medicine;

The field of dance medicine is still quite young, and many areas of research are still unexplored. There are many difficulties still in the field; both having to do with the dance environment itself but also concerns of economics and lack of standardized norms when dealing with dancers. I see also that the vast majority of dance research and literature come from the USA, but hopefully the expertise from the USA will spread to other countries the next couple of years.

In addition there are seldom "many sides to an argument" when diving into the dance medicine literature. As the field is young and the researchers are few most aspects are agreed upon and only discussed by a few authors. Whether the agreement often found is due to the lack of available authors, or due to actual agreement, is for me uncertain. I can clearly see how many of the same authors appear over again in several articles, books and institutional works, and being a member of the International Association of Dance Medicine & Science you also see how the same people again are present. A positive aspect of the field however is the quite broad collection of people from different branches of medicine cooperating; dancers, dance teachers, physiotherapists, medical doctors and experts of biomechanics, kinesiology and general sport medicine.

There is in my opinion a large need for a holistic approach when dealing with dancers. There are so many aspects that are specific to dance that always must be considered; mentality, training regimes, physical requirements, artistic and esthetic requirements, environment, clothing and footwear and not to mention special health issues as eating habits and what it may produce. It would, without a doubt, be beneficial if all dance institutions and companies would have the opportunity to include all these aspects of the dancers overall health into their

daily lives; not only dance itself. This also seems to be the overall agreement found in the literature, but how realistic it is can of course be discussed. Incorporating all this into the normal routine would of course give challenges in economics and also in finding the time without having to decrease time spent in dance training.

Dancers are often trained from a very young age, and often early pushed beyond their limits. I think it is important to emphasize the importance of improving knowledge about technique, injury and prevention not only to older more experienced dancer in companies, but also to younger dancers and their teachers. Better knowledge in anatomy and kinesiology would not only prevent injury, but also enhance technique and ability of the dancers to perform longer without being injured.

As there are so many different aspects to prevention of injury, and also so many different possible approaches, I would myself put pressure on the importance on an individual approach to this topic. If someone was to ask me now what the best approach to prevention would be my answer would simply be a *holistic and individual approach*. As with all humans dancers are also different from one another, and for that simple reason the prevention also needs to be different. Our postural habits and movement patterns are seldom the same, the mentality can differ from person to person and the effects of a training regime can vary. Before writing this thesis, and before studying physiotherapy, I as a young dancers assumed that all my problems could be fixed through finding that one simple fix, and my impression is that most young dancers think like this; showing that they lack an understanding of how complex our body is.

Through the writing of this thesis I feel I have gained a deep look into the field of dance medicine; I have seen how injuries are quite common, often with low severity and high functional disability. I have seen how many injuries develop through dance-specific etiologies and how they can be prevented through improving technique, strength, movement patterns and habits. I have seen that there are several popular approaches to prevention, but still with little scientific proof. I have gained an insight into the dancer's general health and mentality, and I have realized that a holistic approach would benefit dancers the most. It is clear however that the dance medicine field needs more research to back up its stand-points and is only in the beginning of its development.

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Tables

Table 1: Epidemiology Statements

List of epidemiological statements found during literature review and the authors that support the statements.

STATEMENTS found in literature	**SUPPORT from literature**
Lower extremity injury is most common, compared to other body parts.	(3) (4) (20) (43) (44) (45) (46) (47) (26) (40) (7) (12) (8)
Overuse injury is the most common type of injury.	(3) (4) (9) (17) (20) (43) (44) (40) (26) (48) (7) (12) (8)
Foot/ankle is the most common injury area of the lower extremity.	(3) (4) (19) (44) (45) (47) (26) (40) (49) (12)

Table 2: Common Injuries

List of the injuries classified as common by Harkness Center for Dance Injuries.

Foot and Ankle	**Thigh and Knee**	**Hip**
Dancer`s Fracture	Anterior Knee Pain	Trochanteric Bursitis
Sesamoiditis	Knee Hyperextension	Snapping Hip
Hallux Valgus and Bunion	Patellar Malalignment	Illiacus Tendinitis
Hallux Rigidus	Patellar Femoral Syndrom	Prirformis Syndrom
Plantar Fasciitis	Patellar Tendonitis	Femoral stress fracture
Metatarsalgia	Plica Syndrome	Osteoarthritis
Achilles Tendinitis	Meniscus Tear	
Trigger Toe/FHL Tenosynovitis	Medial Collateral Ligament Tear	
Posterior Impingement Syndrome	Anterior Cruciate Ligament Tear	
Anterior Impingement Syndrome	Osteoarthritis	
Lateral Ankle Sprain		

Appendix

Appendix 1: Injury Frequencies by Harkness Center for Dance Injuries

Retrieved 14.12.2011 from:
http://hjd.med.nyu.edu/harkness/dance-medicine-resources/resource-papers-and-forms

HARKNESS CENTER for Dance Injuries

Injury Frequencies

This table illustrates the common dance injuries in various forms of dance, at various levels of participation. Overall, across all styles of dance, injuries of the lower extremity are by far the most common.

AUTHOR	LEVEL& STYLE NUMBER OF INJURIES	INJURY SITE AND DISTRIBUTION
Quirk '84	Mixed level ballet (2113)	22.3% ankle
		20.1% foot
		17.3% knee
		11.4% "other areas"
		8.6% hip
		8.5% lower back
		7.5% lower leg
Liederbach '85	Professional ballet (256)	48.8% foot and ankle
		18.4% leg
		14.5% low back
		7.4% knee
		7.0% hip
		3.9% neck, upper back, UE
Soloman '86	Professional modern (229)	20.1% knee
		19.6% ankle
		15.3% low back
		14.5% upper back, neck, UE
		11.3% hip
		7.0% lower leg
		7.0% foot
Garrick '93	Professional ballet (309)	37.2% foot and ankle
		23.0% low back
		6.8% knee
Soloman '95	Professional ballet (70)	29.0% ankle
		18.0% foot
		10.5% knee
		9.0% hip/thigh
		8.0% lumbar spine
		8.0% cervical/thoracic spine
		6.5% leg
		6.0% shoulder

Appendix 1 continued:

HARKNESS CENTER for Dance Injuries

Injury Frequencies

		5.0% other
Pedersen '98	Professional Flamenco (30)	30% Knee
		23% Ankle
		20% Back
		17% Foot
		7% Neck
		3% Other
Evans et al. '98	Dancers in West End Shows (58)	18.5% Ankle
		18.5% Lower Back
		16.9% Knee
		13.9% Other
		10.8% Neck
		4.6% Groin
		4.6% Thigh
		4.6% Foot or toe
		4.6% Mid/upper back
		1.5% Shin
		1.5% Calf
Evans et al. '96	Dancers in Broadway Shows (166)	22% Back
		14.5% Knee
		12.5% Ankle
		12% Neck
		10% Foot
		6% Hip
		3% Calf

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Appendix 1 continued:

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Appendix 2: Screening form by Harkness Center for Dance Injuries

Retrieved 14.12.2011 from:
http://hjd.med.nyu.edu/harkness/dance-medicine-resources/resource-papers-and-forms

HARKNESS CENTER for Dance Injuries

HARKNESS CENTER FOR DANCE INJURIES: PREVENTATIVE SCREENING FORM

(Marijeanne Liederbach©1989 v04)

NAME OF DANCER: _____ **TODAY'S DATE:** _____

Gross posture & motion:

A/P

Active 4 shld-scap motion tests		**_____N _____Ab (side if Ab: _____)**
Iliac crest height symmetry		**_____Y _____N**
Scoliometer :	**45°(T6)_____R/L 60°(T12-L1)_____R/L 90°(L3-4)_____R/L**	
Foot:	**Calcaneal eversion (≥4°)**	**_____R _____L (Yes / No)**
	"Number of Toes" Sign	**_____R _____L**
	Pes line	**_____R_____L↑ / ↓**
	Foot type	**_____R_____L Cavus (C) / Planus (P)**
Forward bend test		**_____R (+ / -) _____L (+ / -)**
Backward bend test		**_____R (+ / -) _____L (+ / -)**
March test		**_____R (+ / -) _____L (+ / -)**

Sagittal

Forward head	**_____Y _____N**
Fwd shoulders/kyphotic	**_____Y _____N**
Flat back or sway back	**_____Y _____N (specify: _____)**
Genu recurvatum	**_____R (≥ 15° / <15°) _____L (≥ 15° / <15°)**

Flexibility / ROM:

Standing / Floor Sitting:

Can pt. dome foot?	**_____R(yes/no)**		**_____L(yes/no)**	
Mod. Beighton: ·Thumb-to-thumb	**_____tight**	**_____loose**	**·Toe touch**	**_____tight _____loose**
·Lotus	**_____tight**	**_____loose**	**·HAD straddle**	**_____ (> 90° / ≤ 90°)**

Supine / Long Sitting:

	R	L
Dancer's Thomas: Psoas	**_____tight/loose**	**_____tight/loose**
Rectus	**_____tight/loose**	**_____tight/loose**
ITB	**_____tight/loose**	**_____tight/loose**
Sartorius	**_____tight/loose**	**_____tight/loose**
Hamstring:	**_____ (<120°/≥120°)**	**_____ (<120°/≥120°)**
Active open chain dorsiflexion	**_____(≤5° / >5°)**	**_____(≤5° / >5°)**
Active plantar flexion symmetry	**_____Y**	**_____N**
Passive subtalar joint eversion	**_____(≤5° / >5°)**	**_____(≤5° / >5°)**
Passive great toe dorsiflexion	**_____(<90° / ≥90°)**	**_____(<90° / ≥90°)**
Thomasson sign?	**_____(yes / no)**	**_____(yes / no)**
Hip: Prone HER	**_____ (>45° / <45°)**	**_____ (>45° / <45°)**
Prone HIR	**_____ (>45° / <45°)**	**_____ (>45° / <45°)**

MMT Strength:

Terminal Hamstring	**R_____L_____**		
	R_____L_____		
	x_____x_____	**%Deficit _____**	
Hip Abduction	**R_____L_____**		**Normative Data**
	R_____L_____		**M F**
	x_____x_____	**% Deficit _____**	**22.3 ± 1.7 15.1 ± 0.5**
Hip Adduction	**R_____L_____**		**Normative Data**
	R_____L_____		**M F**
	x_____x_____	**% Deficit _____**	**23.7 ± 0.9 15.2 ± 0.4**
Hip Flexion	**R_____L_____**		**Normative Data**
	R_____L_____		**M F**
	x_____x_____	**% Deficit _____**	**32.0 ± 3.1 22.3 ± 2.1**

Appendix 2 continued:

HARKNESS CENTER for Dance Injuries

Shoulder Abduction	**R____L____**	**Normative Data**	
	R____L____	**M**	**F**
	x ____x ____ % Deficit ____	**12.1 ± 0.7**	**6.2 ± 0.3**

Functional Strength & Skill Tests:

- **Kendall supine double straight leg lower** **_____ (Pass [5/5] _____Fail [≤4/5])**
- **Standing turnout** **_____° Total**
  Disc turnout **_____° Total**
  Force differential **_____ #**
- **First Position Relevé(*note pelvis*- APT/Neutral/PPT):** **_____R_____L**
  - **Normal (calcaneal midline & mid patella aligned with 2nd ray)**
  - **Med (calcaneal midline & mid patella medial to 2nd ray)**
  - **Lat (calcaneal midline & mid patella lateral to 2nd ray)**
- **Calcaneal height symmetry test (L & R same height?)** **_____Y _____N**
- **Functional DF ROM - first position parallel plié** **_____R _____L**
  Pass (plumb line from patella to toe tips or distal)
  Fail (plumb line from patella to met heads or proximal)
- **Second Position Progression Angle of Knee (*note pelvis* – APT/Neutral/PPT):** **_____R_____L**
  - **Normal (knee over second ray)**
  - **Min (knee over first ray)**
  - **Mod (knee just medial to first ray)**
  - **Max (knee grossly medial to first ray)**
- **Rhomberg (pass/fail)** **_____R_____L**
- **Single leg strategy (hip/ankle)** **_____R_____L**
- **25 Heel Raises in neutral parallel 1st** **_____R_____L**
  Pass: maintains full heel height over consecutive 1-second repetitions without knee flexion moment
  Fail: unable to maintain above criteria
- **5 Single Leg Bench Step Down (eyes open & closed)** **_____R_____L (EO)**
  _____R _____L (EC)
  Pass: maintains patellar center over 2nd ray
  Fail: demonstrates valgus - patellar center medial to 1st ray or LOB)
- **"Airplane" Pliés with Trunk Rotation & Proprio Overload** **_____R _____L**
  Pass: 5 demi pliés on pillow, pitched fwd // arabesque, maintaining LE alignment & balance during B 90° trunk and gaze rotation
  Fail: loses control of above criteria
- **5 Pushups with trunk control (plank and inverted (handstand)** **_____P ____F (plank)**
  _____P ____F (inverted)
- **5 Plank → side plank (one arm, one foot balance) pose** **_____R _____L**
  Pass: able to do consecutive B plank to side plank rotations with slow, steady control
  Fail: fatigues, loses trunk control or balance
- **Jumping**
  Parallel Single Leg "Sauté" or "High Jump" (height) **_____R (in.) _____L (in.) _____ΔR/L**
  Parallel Single Leg "Jeté" or "Long Jump" (distance) **_____R (in.) _____L (in.) _____ΔR/L**
- **Harvard bench step test** **_____P_____F**
  (bpm: ____) (bpm @ 1 min post: ___)

Special Orthopedic Tests:

Appendix 3: Questionnaire done at Langhaugen Dance High School

Anonymous review questionnaire given to students after 3 lectures in August 2011. Translated from Norwegian.

REVIEW QUESTIONARE – Langhaugen August 2011

1. Do you feel you have learned something from the past three lectures that will contribute positively to your dance training/dance life?

2. Is there anything in particular we have spoken about that you felt was especially important for you? Why?

3. Do you feel you will be able to use the information from these lecture practically in your life with dance?

4. Do you think regular lectures like this would benefit the dance students?

5. Was the lecture organized and easily understood?

6. Do you further have any comments?

Appendix 4: Summarized Causes of Specific Diagnosis

Hip:

Snapping hip;

- Wide pelvis, prominent trochanter, ligamental laxity
- Weakness hip abductors
- Sitting in the hip
- Tightness of Illiotibial band
- Failure to maintain turn out

Illiopsoas tendinitis:

- Thigh hip flexors
- Preexisting snapping hip

Trochanteric Bursitis;

- Falling on the hip
- Poor biomechanical alignment
- Weakness of external rotators and abductors
- Tightness of Illiotibial band
- Leg length discrepancies, increased collum anteversion, broad pelvis
- Overpronation of feet
- Alteration of gait pattern due to back pain
- Gluteal tendon degeneration or tears at the trochanteric insertion
- Obesity or arthritis
- Additional diagnosis as scoliosis, snapping hip, lumbosacral radiculopathy, sacroiliac disturbances

Knee:

Patellofemoral pain:

- Faulty biomechanics of lower extremity
- Lower ext. malalignment as increased femoral anteversion, tibial torsion and foot pronation.
- Poor technique, especially improper use of quadriceps during pliè.
- Screwing the knee to have more turn out
- Tightness of Illiotibial band,
- Poor core muscle control leading to increased anterior pelvic tilt, femoral internal rotation, tibial external rotation and foot pronation as compensation.

Patellar Tendinitis:

- Poor training or technique
- Hard surface or poor footwear
- Cheating with turn out giving extra torsion stress to knee

Meniscus tear:

- Forced rotation or twisting of knee
- Valgus stress to knee
- Hyperextension or hyperflexion mechanism
- Attempts to increase turn out
- Excessive Grand pliè
- Faulty landing from jumps
- Weakness of adductors and Vastus Medialis this giving a lateral pull at the knee.
- General imbalance around the knee

Foot and Ankle:

Hallux Valgus

- Genetics, gender, other feet conditions, length and shape of the big toe
- Footwear
- Imbalance between adductor hallucis and abductor hallucis longus.
- Excessive foot pronation due to tries to achieve better turn out.

Hallux Limitus/Rigidus:

- Flat foot, narrow foot, genetics
- Pronated foot
- Abnormalities of hallux and metatarsus primus varus
- Shoes
- Occupation
- Arthritic disorders
- Obesity
- Repeated trauma
- Forced turn out
- Forced demì pointè position

Sesamoiditis:

- Trauma
- Prolonged work on hard surface
- Hyperpronation of feet
- Forced turn out
- Incorrect landing from jumps
- Sacroiliac dysfunction
- Repetitive and/or incorrect relevè.
- Footwear

Dancer`s Fracture:

- Direct trauma to lateral foot
- Falling from demì pointè position or landing from a jump on an inverted foot
- Landing on inverted and plantarflexed jumps, often seen in modern dance.
- General ankle instability
- History of ankle problems
- Peroneal weakness

Lateral Ankle Sprain:

- History of ankle sprains
- Fatigue
- Poor landing technique
- Poor floor construction or footwear
- Forced turn-out
- Poor ankle stability or coordination
- Weakness of peroneal muscles and intrinsic feet muscles
- Postural insufficiency
- Anatomical predispositions as genu varum and increased talar tilt

Achilles Tendonitis:

- Overuse of calf muscles
- Improper warm up or class progression

- Short calf muscles
- Excessive pronation or supination of foot
- Weakness of feet including intrinsic muscles of foot, Gastrocnemius, quadriceps, hamstrings and Gluteals
- Low relevè; gives extra stress on tendon
- Hyperextension of knees
- Weight bearing to far back on foot
- Footwear and floor without shock absorption
- Anatomical variations of feet or achilles

Shin Splints:
- Running or jumping
- "Doing too much too soon"
- Traction injury fro medial soleus muscle
- Bone stress reaction
- Foot pronation
- Training errors
- Hard surface or improper shoes
- Tightness of Gastrocnemius and Soleus propelling the body forward putting stress on tibialis anterior
- Muscle imbalance between dorsiflexors and plantarflexors with decreased dorsiflexion
- Leg length discrepancy
- Tibial torsion
- Excessive femoral anteversion
- Inadequate warm up

Anterior Ankle Impingement:
- Repetitive excessive dorsiflexion like pliè
- Predisposing factor may be repetitive ankle strains.

Posterior Ankle Impingement:
- Excessive plantarflexion, as with en pointè positions
- Presence of an Os Trigonum

Flexor Hallucis Longus Tendonitis:
- Mostly caused by anatomical situation where the tendon is stuck in the tunnel during a dorsiflexion, as pliè, onto a full plantarflexion.
- Malalignment of foot
- Faulty technique as foot pronation